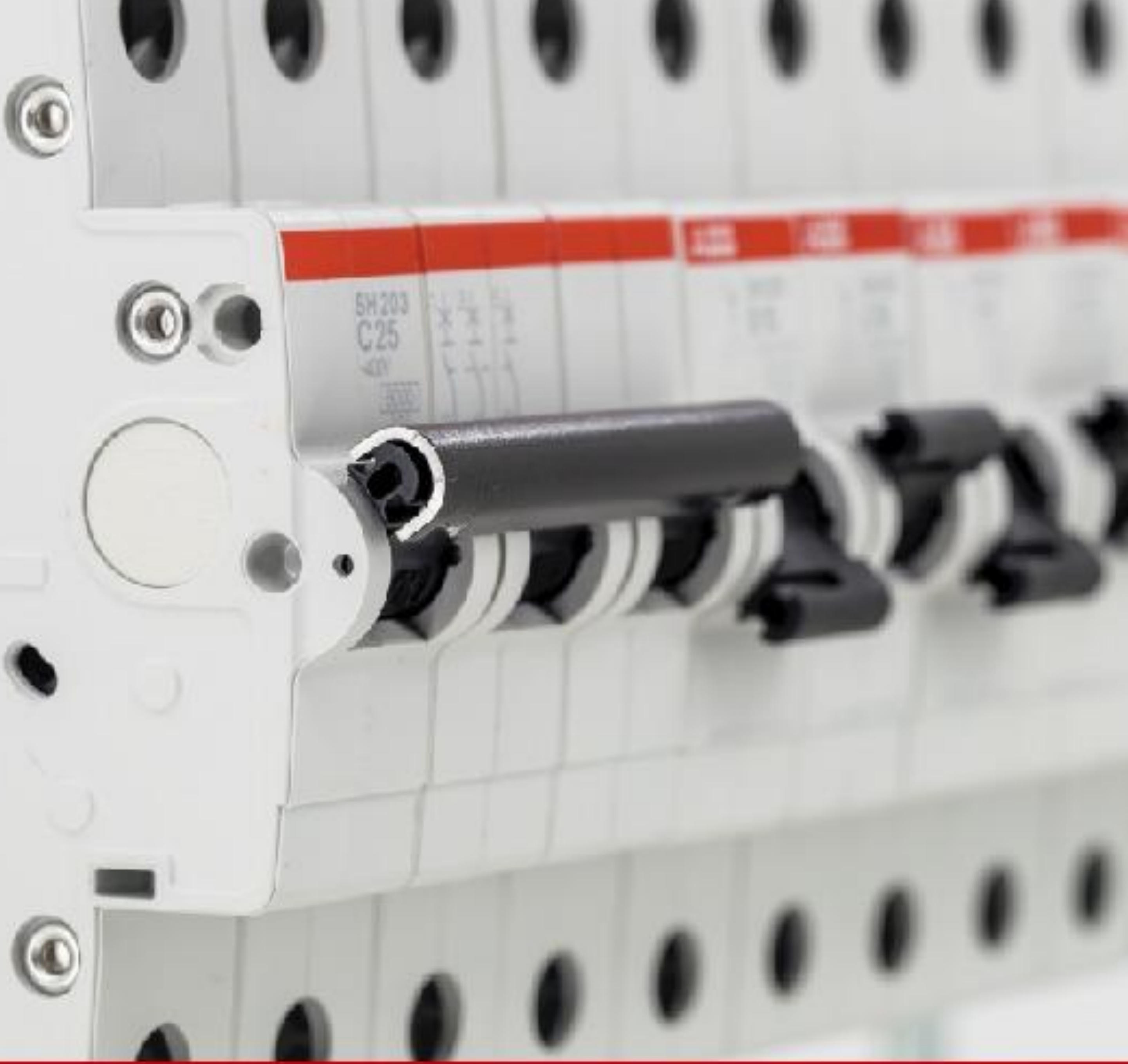

ELECTRICAL CIRCUITS

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ELECTRICAL CIRCUITS

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PREFACE

This e-book of Electrical Circuits presents the fundamentals of electrical circuit principles which divided into five main element: alternating voltage and current, sinusoidal steady-state circuit analysis, resonance, transformers and three phase system. Each element is comprehensively explained in an informative infographic as to attract the students as well as to ease their understanding towards the electrical circuit principles. Besides, this e-book is written to provide the possible problems in the electrical circuits which can guide students to the real final examination questions. This is important in order to ensure the students in achieving the determined Course Learning Outcomes (CLO) and Programme Learning Outcomes (PLO) , as outlined by the Curicular Division, Jabatan Pengajian Politeknik dan Kolej Komuniti (JPPKK). Hopefully, this book will enrich the student's theoretical knowledge of the electrical circfuits as well as it also can assist the electrical engineering academic staff as one of their teaching aid and reference.

Normazlina Mat Isa, PhD
Author.

Table of content

Chapter 1: Alternating Voltage And Current

- Alternating current
- Generation of Alternating Current
- Sinusoidal voltage and current values of a sine wave
- Sinusoidal wave for an angular measurement
- Phasor to represent a sine wave
- Basic circuit laws of resistive AC circuits

DIRECT CURRENT (DC)

• *Direct current* (DC), which is electricity flowing in a constant direction, and/or possessing a voltage with constant polarity.
• The magnitude of voltage and current in a DC circuit is always constant at any point of time

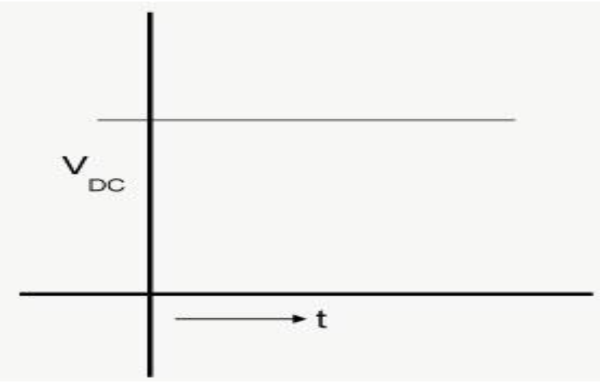


Figure 1 : Direct Current

ALTERNATING CURRENT (AC)

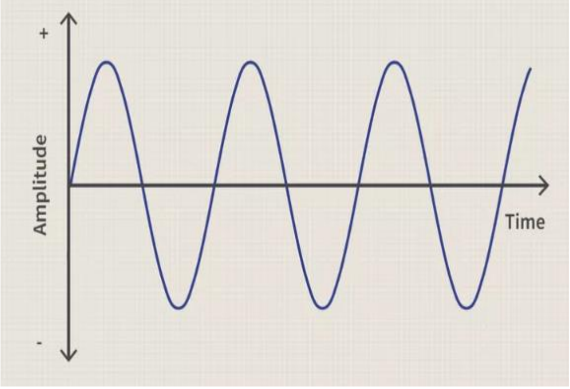


Figure 2 : Basic Alternating Current

• A current which varies is known as an alternating current.
• It flows first in one direction and then in the other.
• The cycle of variation is repeated exactly for each direction
• The curves relating current to time are known as waveform.
• Those shown in Figure 2 and 3 are simple waveforms

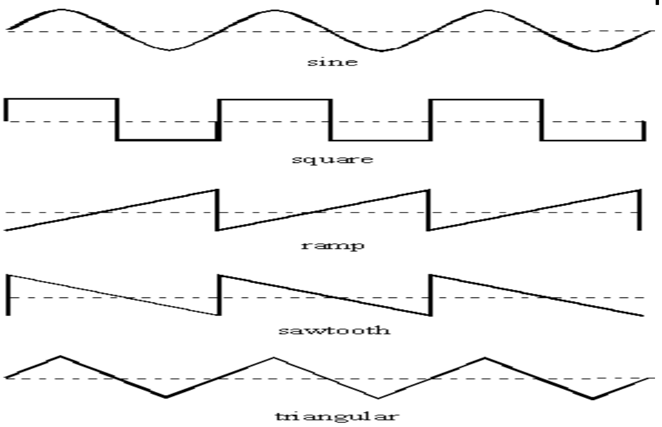


Figure 3 : Alternating current waveform

Alternating Current Source

In electricity generation, an electric generator is a device that converts mechanical energy to electrical energy

Direct current VS Alternating current

- Alternate current (AC) is the type of electricity typically used in households.
- With AC, the magnitude and direction of electricity vary.
- Direct current (DC) is a source of electricity that does not vary in direction.
- An example of a DC source is a battery, or solar cells.
- The main difference between the two types of currents is simply the direction, as made quite clear by the names:
- Alternate current cannot stored but direct current can be stored examples in case of battery cells

Generation of an alternating current

There are two methods to generate of an alternating current:

- Moving conductor, magnetic flux is static
- Moving magnetic flux, the conductor at static

AC GENERATOR

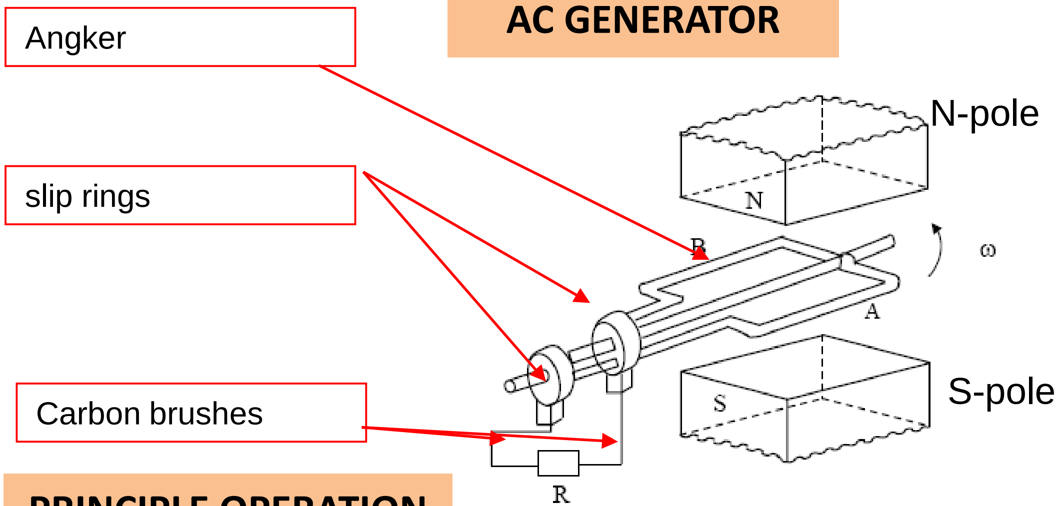


Figure 4: AC generator

PRINCIPLE OPERATION OF AC GENERATOR

- When the plane of the loop is horizontal, the two sides A and B are moving parallel to the direction of the magnetic flux.
- It follows that no flux is being cut and no e.m.f is being generated in the loop.
- The effects which occur as the coil is rotated, therefore the coil sides are cutting the flux and e.m.f is induced in the coil sides.
- Since, the coil sides are moving in opposite directions, the e.m.f act in opposite directions.
- However, they do act in the same direction around the coil so that the e.m.f which appears at the brushes is twice that which is induced in a coil side.
- Once the coil reaches the position the rate of the coil has rotated to the position.

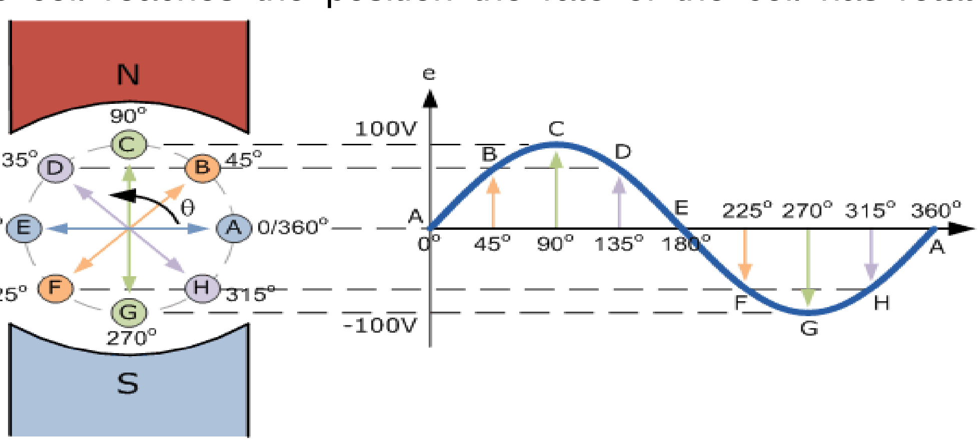


Figure 4: Sine wave of e.m.f

FARADAY's LAW

What is Faraday's Law?

Faraday's law of electromagnetic induction (referred to as **Faraday's law**) is a basic law of electromagnetism predicting how a magnetic field will interact with an electric circuit to produce an electromotive force (EMF). This phenomenon is known as electromagnetic induction.

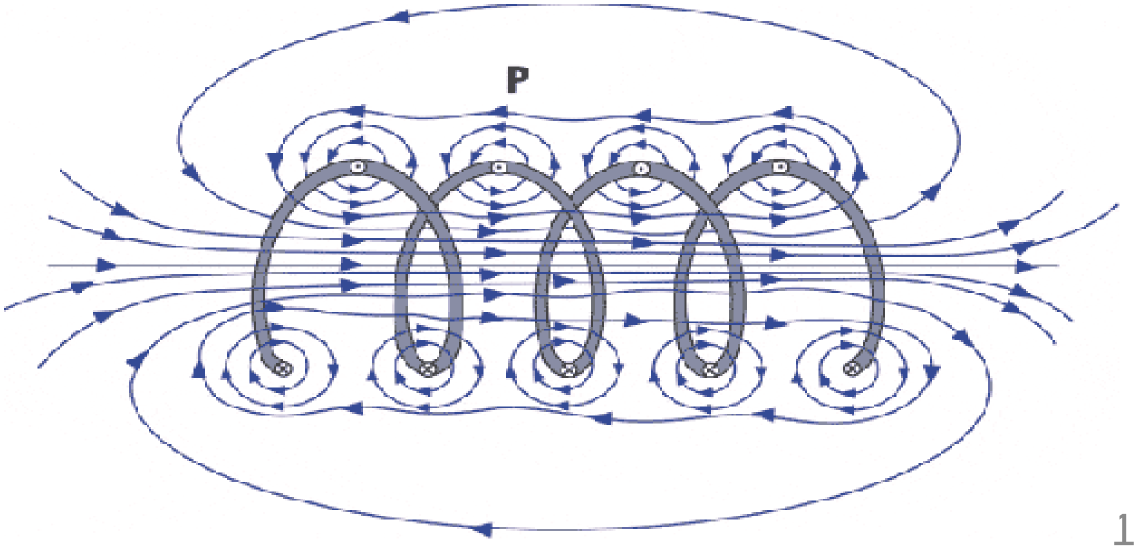
What Faraday's Law tell us???

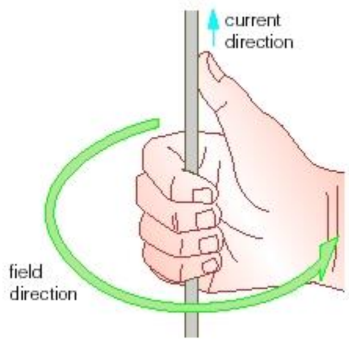
- Michael Faraday stated that **electromotive force (EMF)** produced around a closed path is proportional to the rate of change of the magnetic flux through any surface bounded by that path.
- In practice, this means that an electric current will be induced in any closed circuit when the magnetic flux through a surface bounded by the conductor changes
- This applies whether the field itself changes in strength or the conductor is moved through it.

As a young man in London, **Michael Faraday** attended science lectures by the great Sir Humphry Davy. He went on to work for Davy and became an influential scientist in his own right. Faraday was most famous for his contributions to the understanding of **electricity** and **electrochemistry**.

Ref:

https://sciencehistory.org/education/scientific-biographies/michael-faraday/





Right-Hand Grip Rule

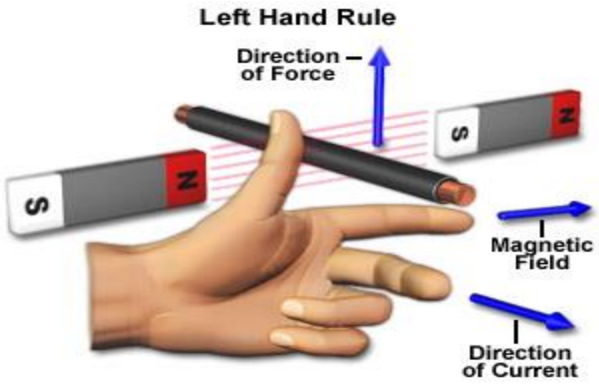
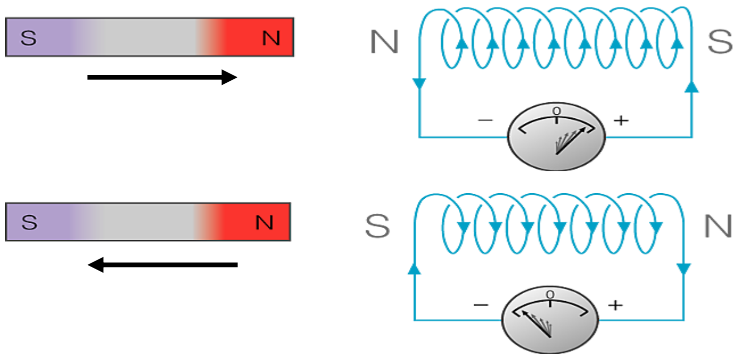


Figure 5: Methods of generating AC

LENZ's LAW

Lenz's law introduced by **Heinrich Friedrich Emil Lenz**, states that the induced **electromotive force with different polarities induces a current whose magnetic field opposes the change in magnetic flux through the loop in order to ensure that the original flux is maintained through the loop when current flows in it.** The induced I always flows to oppose the movement which started it. In both cases, magnet moves against a force as well as the work is done during the motion and it is transferred as electrical energy.

Reference;
Lezhneva, Olga (1970–1980). "Lenz, Emil Khristianovich (Heinrich Fridrich Emil)". Dictionary of Scientific Biography. Vol. 8. New York: Charles Scribner's Sons. pp. 187–189. ISBN 978-0-684-10114-9.



Magnetic field due to solenoid

In both cases, magnet moves **against a force. Work is done** during the motion & it is transferred as electrical energy.

An equation of a sinusoidal waveform

$e = E_m \sin \theta$	$e = E_m \sin \varpi t$	$e = I_m \sin \theta$

Hence,

e = Instantaneous voltage in A.C quantity

Em = Maximum value of A.C voltage

Im = Maximum value of A.C current

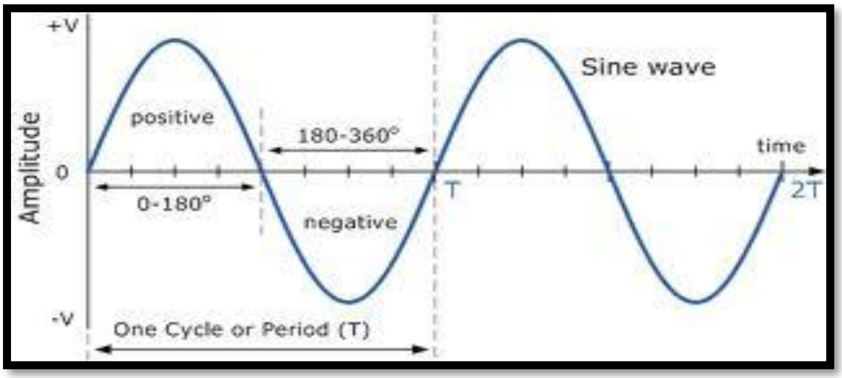
ϖ = Angular velocity of the coil, $2\pi\mathbf{f}$ **atau** $\frac{2\pi}{T}$

- A rotating coil moves 360º in one revolution.
- At 180º, the current or voltage decreases positively and
- at the other 180º the current or voltage decreases negatively.
- In radian, one complete cycle is 2π radian.
- Period of one cycle is T

WAVEFORM TERMS AND DEFINITIONS

Waveform: The variation of quantity such as voltage or current shown on a graph to a base of time or rotation

Cycle: Each repetition of a variable quantity, recurring at equal intervals



Period : The duration of one complete cycle
Symbol : T , Unit : Second (s)

Instantaneous value: The magnitude of a waveform at any instant in time

Frequency : The number of cycles complete in a second
Symbol : F
Formula : 1 / T
Unit : Hertz

Peak amplitude: The maximum instantaneous value measured from the mean value of a waveform

Peak value (Vp): The maximum instantaneous value measured from zero value

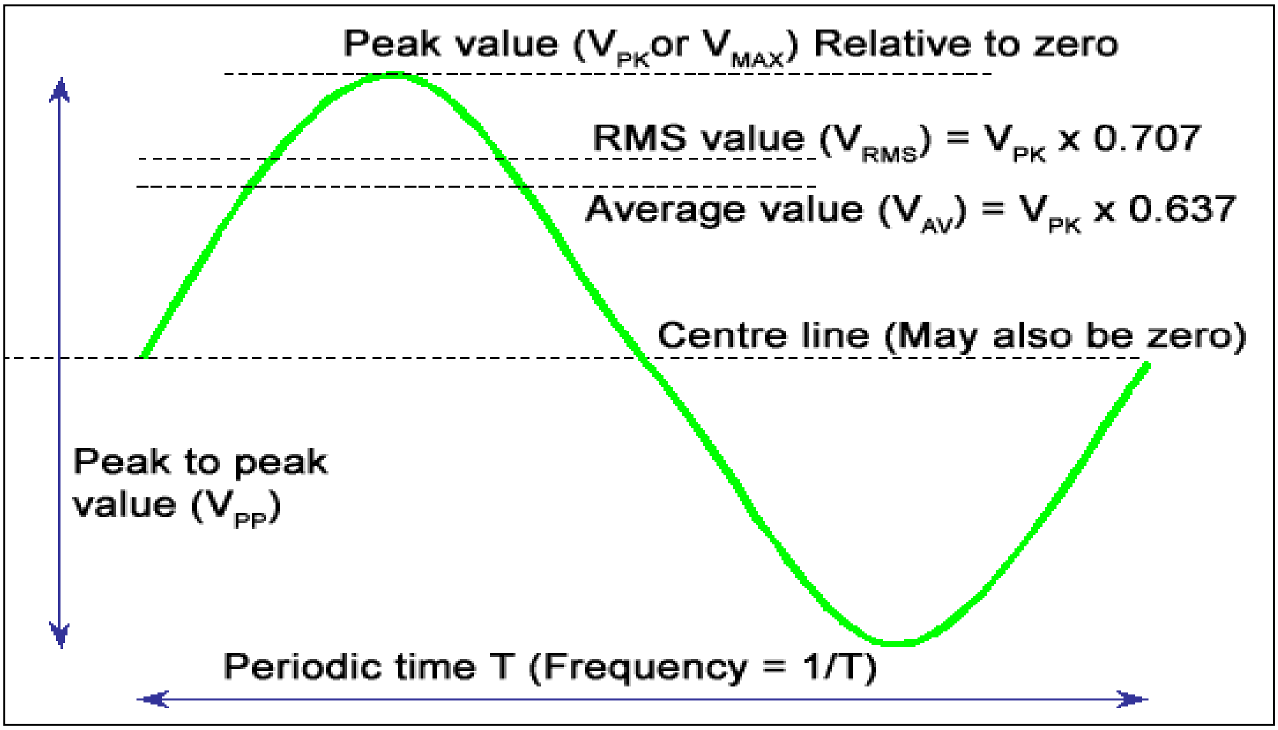
Peak-to-peak value (Vpp): The maximum variation between the maximum positive instantaneous value and the maximum negative instantaneous value

Average value

- An alternating waveform has to be taken over half a cycle
- Average value = 0.637 x peak value(Vp)
- hence, Average value = 2 Vp / π

Root mean square (RMS) value

- An alternating waveform can be taken over half a cycle or over a full cycle
- RMS value = 0.707 x peak value(Vp)
- Hence, 0.707 = 1 / √2



Form factor = rms value / average value = 1.11

$$\text{Form factor} = \frac{\text{rms value}}{\text{average value}} = \frac{0.707 \times \text{peak value}}{0.637 \times \text{peak value}} = \mathbf{1.11}$$

Peak factor = peak value / 0.707 peak value = 1.414

$$\text{Peak factor} = \frac{\text{peak value}}{\text{rms value}} = \frac{\text{peak value}}{0.707 \times \text{peak value}} = \mathbf{1.414}$$

Angular measurement of sine wave

Convert radian and degrees

$$\text{Radians} = \left(\frac{\pi}{180^0}\right) \times \text{degrees}$$

$$\text{Degrees} = \left(\frac{180^0}{\pi}\right) \times \text{radians}$$

The phase angle of a sine wave

$$30^o \rightarrow \text{Radians} = \frac{\pi}{180^o}(30^o) = \frac{\pi}{6}\text{ rad}$$

$$90^o \rightarrow \text{Radians} = \frac{\pi}{180^o}(90^o) = \frac{\pi}{2}\text{ rad}$$

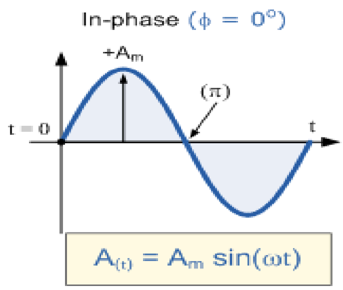
$$\frac{5\pi}{4}\text{rad} \rightarrow \text{Degrees} = \frac{180^o}{\pi}\left(\frac{5\pi}{4}\right) = 225^o$$

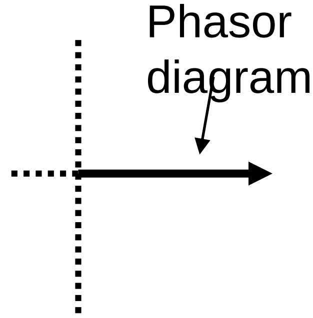
$$\frac{3\pi}{2}\text{rad} \rightarrow \text{Degrees} = \frac{180^o}{\pi}\left(\frac{3\pi}{2}\right) = 270^o$$

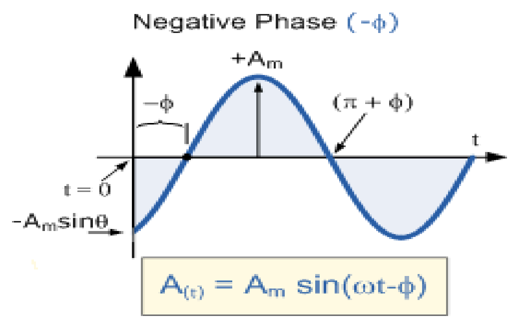
Phasor to represent a sine wave

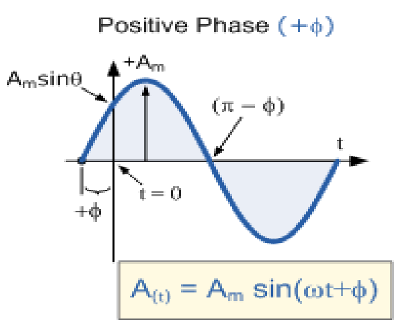
- PHASE DIFFERENCE(PHASE SHIFT)
  - a sinusoidal waveform is a angle Φ in degrees or radians that the waveform has shifted from a certain reference point along the horizontal zero axis.
- PHASOR
  - scaled line whose length represents an AC quantity that has both MAGNITUDE (peak amplitude) and DIRECTION (phase) which is frozen at some point in time.
  - rotates in an anti-clockwise direction at an angular velocity (ω) of one full revolution for every cycle
    - anti-clockwise (+ve rotation)
    - clockwise (-ve rotation)

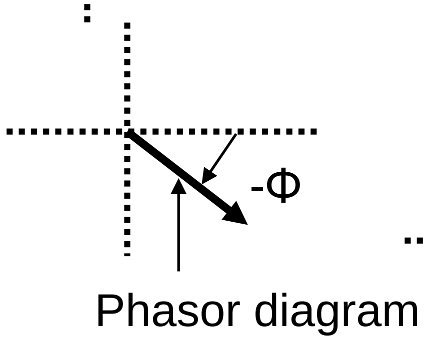
Phase Relationship of a Sinusoidal Waveform

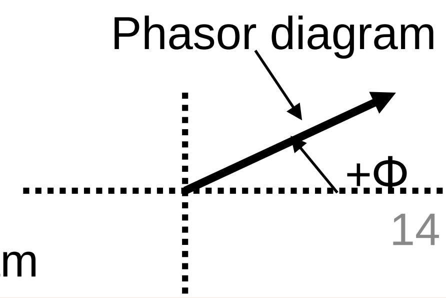






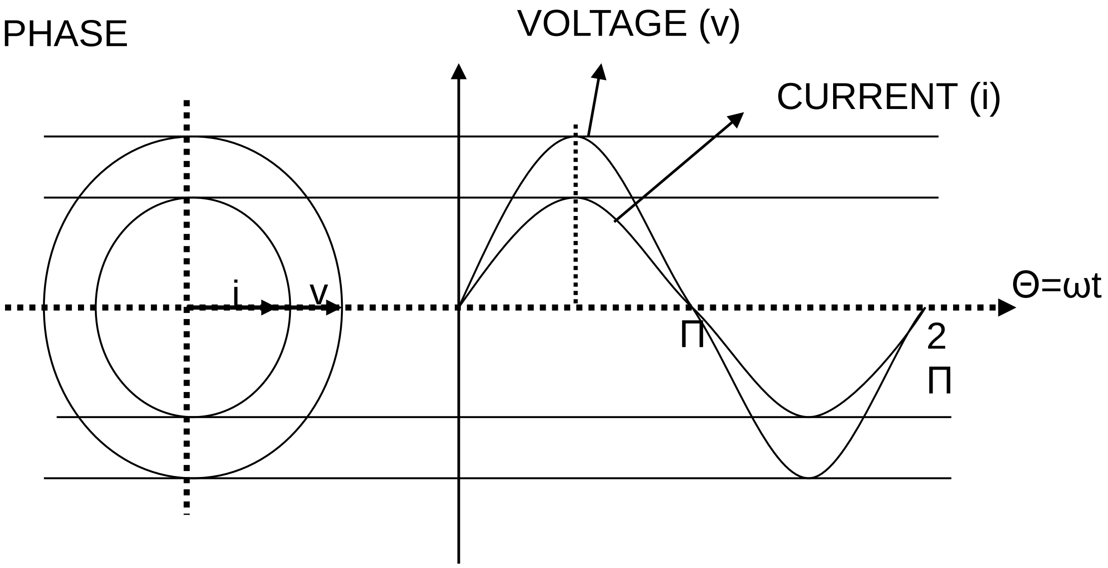






TWO SINUSOIDAL WAVEFORM

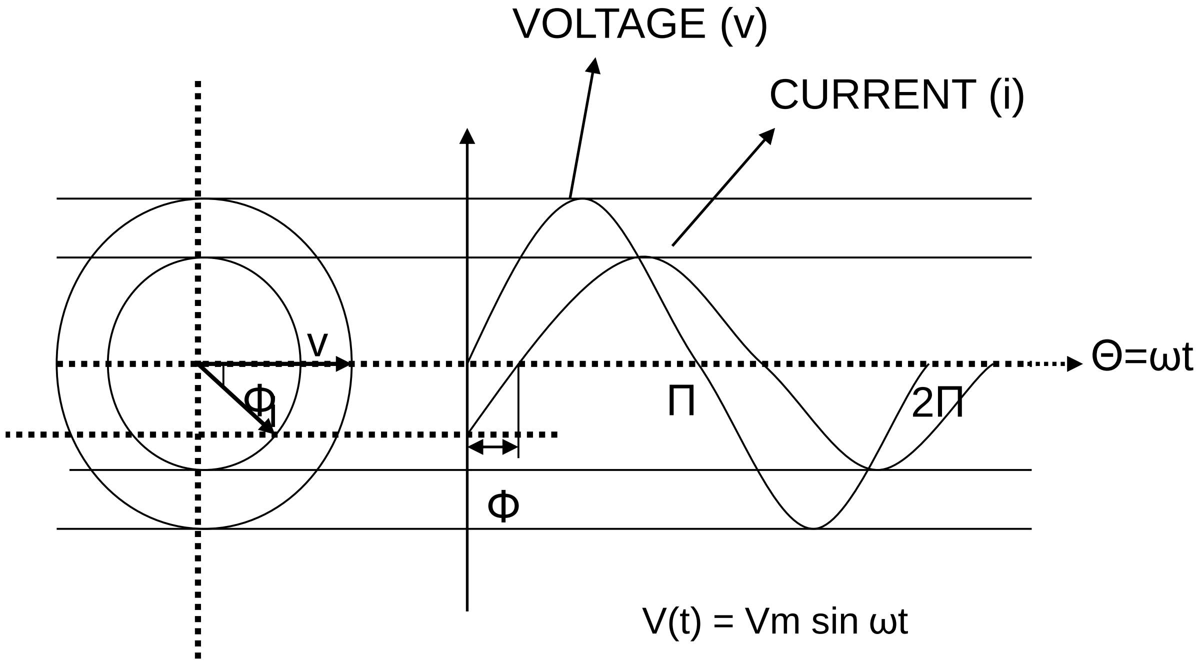
a) IN PHASE



$$V(t) = Vm \sin \omega t$$

$$i(t) = im \sin \omega t$$

b) LAGGING PHASE DIFFERENCE

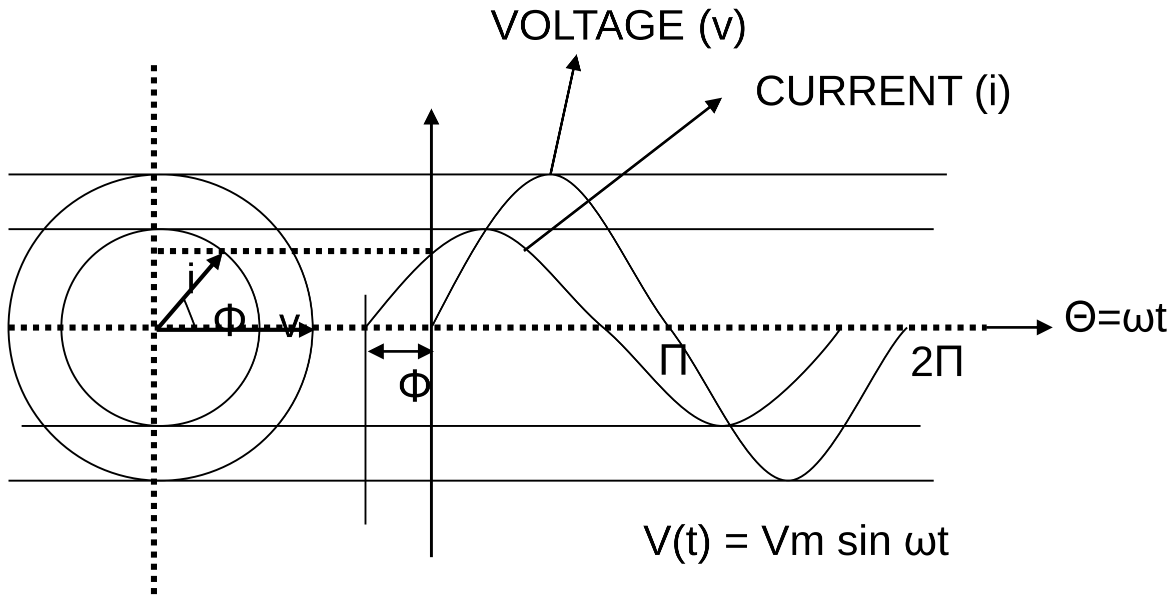


$$V(t) = Vm \sin \omega t$$

$$i(t) = im \sin (\omega t - \Phi)$$

i is said to lag v by angle Φ

c) LEADING PHASE DIFFERENCE



V(t) = Vm sin ωt

i(t) = im sin (ωt + Φ)

i is said to lead v by angle Φ

TRIGONOMETRIC IDENTITIES

-sin = sin (ωt + 180^o) sin = -sin (ωt – 180^o)	-cos = cos (ωt + 180^o) cos = -cos (ωt – 180^o)
cos = sin (ωt + 90^o) -cos = sin (ωt – 90^o)	sin = cos (ωt - 90^o) -sin = cos (ωt + 90^o)

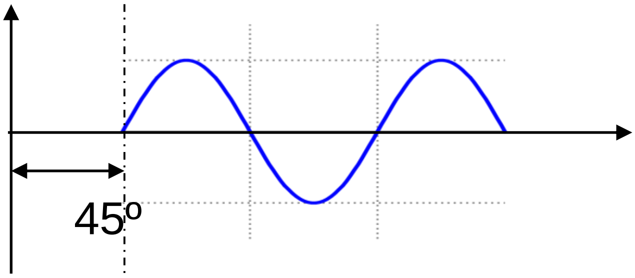
TEST-MIND!!!

1. Why AC is used in preference to DC?
2. List two methods on how to generate alternating current?
3. Refferring to the equation below, which one lags the other,and by how many degrees?

   i = 25mA sin(θ - 15^o)

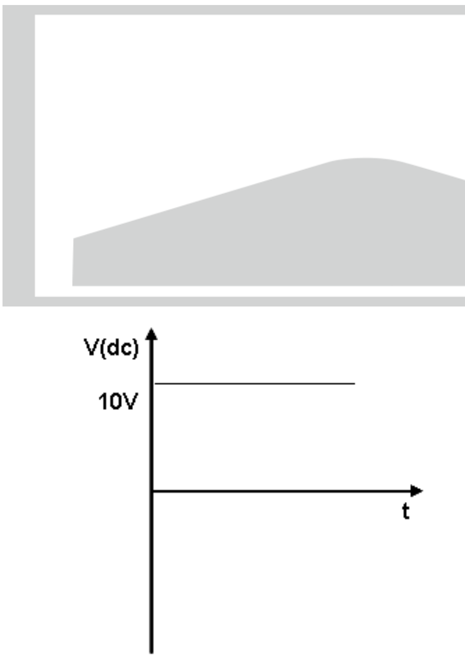
   v = 12V sin(θ + 20^o)

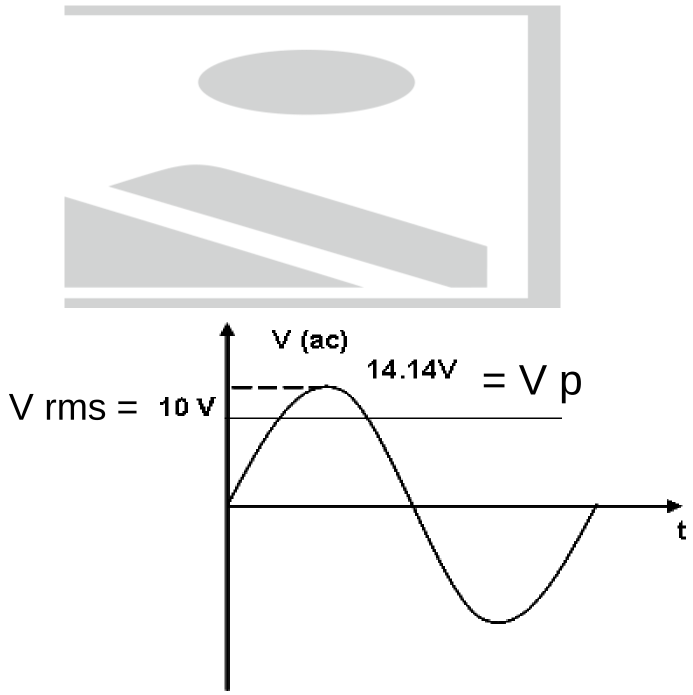
4. State the voltage equation for waveform diagram :



Basic circuit laws of resistive AC circuits

DC circuits **AC circuits**



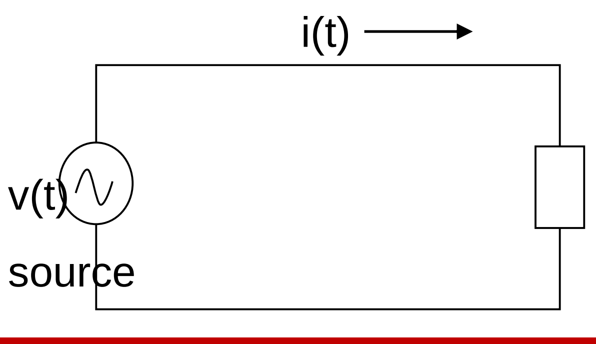


10Vdc value is equivalent 10Vrms value AC
DC resistance = AC impedance
R = Z

- Pure resistor in AC circuits
  - The same principals of Ohm's Law
    - Vrms= Irms Z
  - Kirchoff's Law
    - Kirchoff Voltage Law (KVL)
      VT = V1+V2+Vn……
    - Kirchoff Current Law (KCL)
      ∑I in close circuit = 0 (Iin = Iout)
- In AC circuits, the voltage and current is using rms value for calculation

POWER IN AC CIRCUIT

- Instantaneous power
  - The power at any instant of time
  - P(t) = v(t) X i(t)



LOAD = Z<θ

There are 3 types of instantaneous power in AC:

1)Apperant power(S)

- The product of the rms values of voltage and current ,

  S =Vrms Irms

- The unit is VA

2) Average power (P)

- The average of the instantaneous power over one period. The unit is Watt (W)

P = Vrms Irms cos θ

Where θ = 0°,because pure resistor

So;

- **P = Vrms Irms = $Vrms^2$ / ZT = $Irms^2$ Z**

3) Reactive power (Q)

- The product of the applied voltage and the reactive component of the current. The unit is VAR

  Q = Vrms Irms sin θ

Power factor

- Ratio between average power and apperant power
- Power factor = $\frac{\text{average power}}{\text{apperant power}} = \frac{\text{Vrms Irms cos } \theta}{\text{Vrms Irms}} = \cos\theta$

TEST-MIND!!!

1. An alternating voltage is given by v = 75 sin (200Πt – 0.25) volts

Find:

a) the amplitude

b) the peak to peak value

c) the rms value

d) the periodic time

e) the frequency

f) the phase angle (in degree)

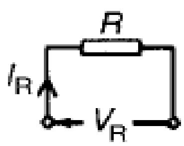
Chapter 2: SINUSOIDAL STEADY - STATE CIRCUIT ANALYSIS

- AC basic circuits
- Circuit with inductive and capacitive load
- Series and parallel R-L-C circuits
- Combination of series R-L-C circuits
- Power in AC circuits
- Power consumption in AC circuits

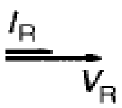
AC basic circuits

PURELY RESISTIVE AC CIRCUIT

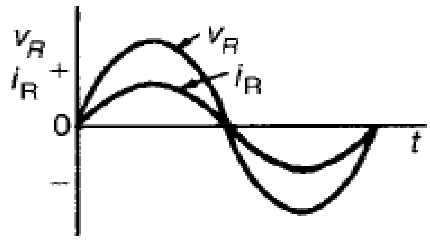
REACTANCE → R=V/I



Circuit diagram



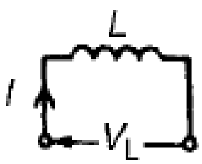
Phasor diagram



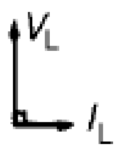
Current and voltage waveforms

PURELY INDUCTIVE AC CIRCUIT

REACTANCE → XL=VL/IL @ XL=2πfL

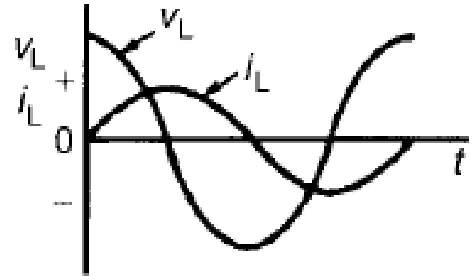


Circuit diagram



I_L lags V_L by 90°

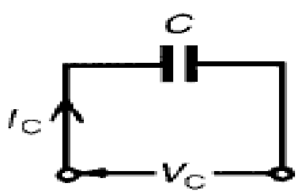
Phasor diagram



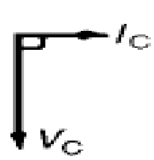
Current and voltage waveforms

PURELY CAPACITIVE AC CIRCUIT

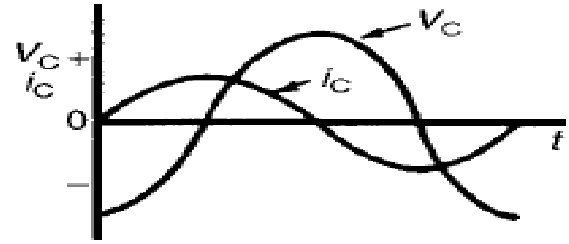
REACTANCE → XC=VC/IC @ XC=1/2πfC



Circuit diagram

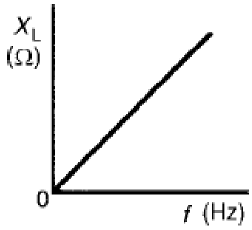


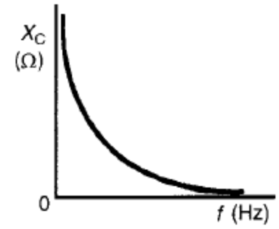
Phasor diagram



Current and voltage waveforms

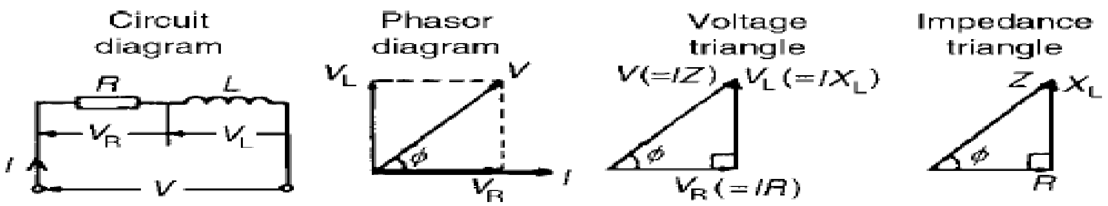
Relationship Between XL/XC and Frequency





A Single-phase SERIES AC circuits

i. RL SERIES AC CIRCUIT



$V = \sqrt{V_R^2 + V_C^2}$ (by Pythagoras' theorem)

For the R–C circuit: $Z = \sqrt{R^2 + X_C^2}$

$\tan \propto = -\frac{V_C}{V_R}$ (by trigonometric ratios)

OR

$\tan\alpha = \frac{X_C}{R}$

$Z = \frac{V}{I}\,\Omega$

$\sin\alpha = \frac{X_C}{Z}$

OR

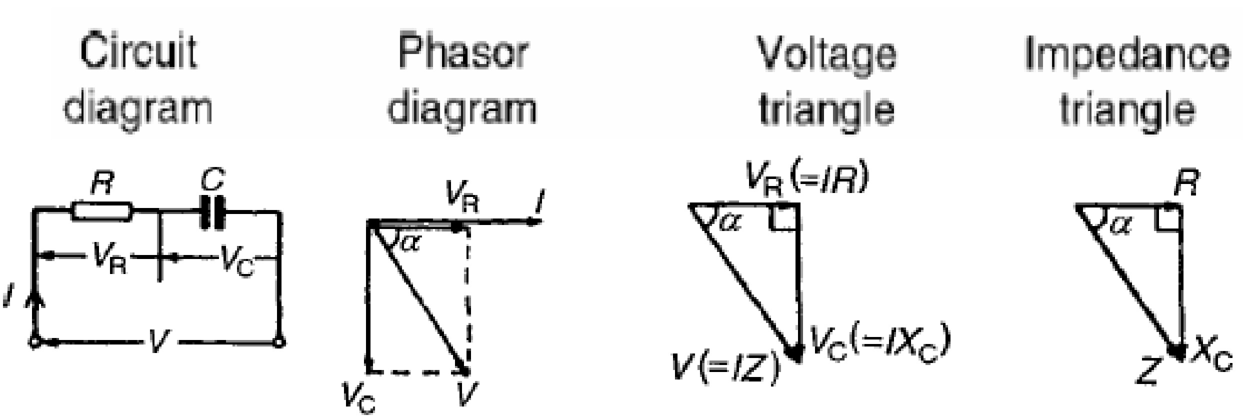
$V = V_R - jV_C$
(rectangular form)

OR

$V = R - jX_C$
(rectangular form)

$\cos\alpha = \frac{R}{Z}$

ii. RC SERIES AC CIRCUIT



For the R–C circuit: $Z = \sqrt{R^2 + X_C^2}$

$V = \sqrt{V_R^2 + V_C^2}$ (by Pythagoras' theorem)

OR

$\tan \propto = -\frac{V_C}{V_R}$ (by trigonometric ratios)

$\tan\alpha = \frac{X_C}{R}$

$Z = \frac{V}{I}\,\Omega$

OR

$\sin\alpha = \frac{X_C}{Z}$

$V = V_R - jV_C$
(rectangular form)

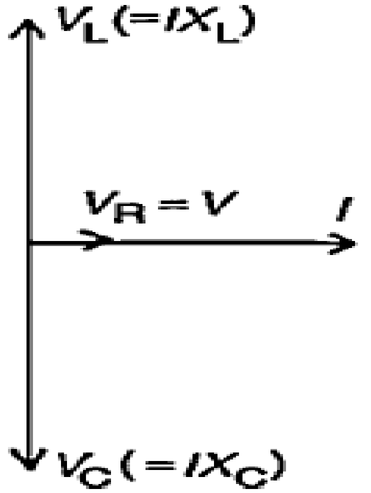
OR

$V = R - jX_C$
(rectangular form)

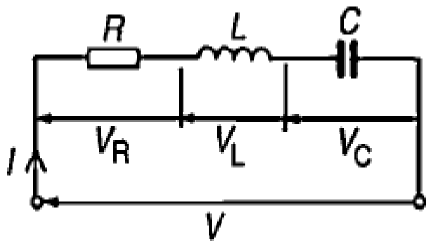
$\cos\alpha = \frac{R}{Z}$

iii. R-L-C SERIES AC CIRCUIT

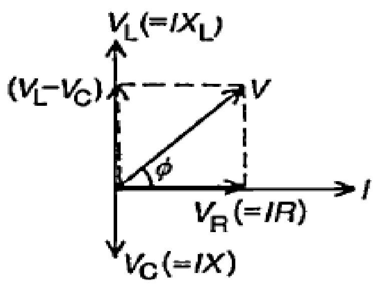
PHASOR DIAGRAM

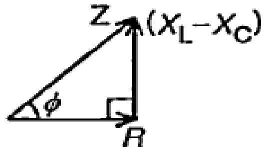


CIRCUIT DIAGRAM



XL > XC



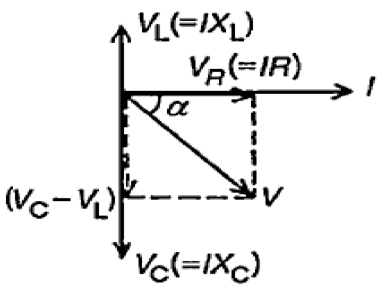


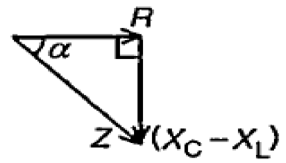
IMPEDANCE TRIANGLE

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\tan \phi = \frac{X_L - X_C}{R}$$

XC > XL





IMPEDANCE TRIANGLE

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

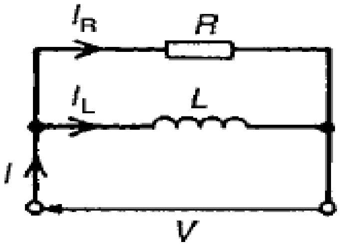
$$\tan \alpha = -\frac{X_C - X_L}{R}$$

TEST-MIND!!!

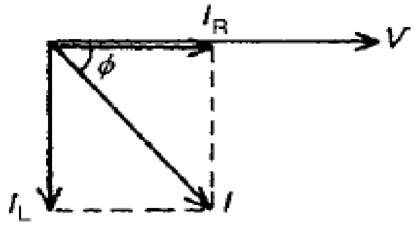
B Single-phase PARALLEL AC circuits

i. RL PARALLEL AC CIRCUIT

Circuit diagram



Phasor diagram



$$I = \sqrt{I_R^2 + I_C^2}$$

$$\tan \emptyset = -\frac{I_L}{I_R}$$

OR

$$I = I_R - jI_L$$

$$I_R = \frac{V}{R}$$

$$I_L = \frac{V}{X_L}$$

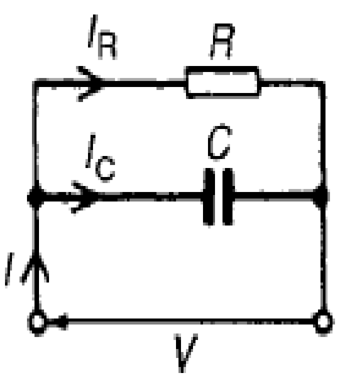
$$\text{Circuit impedance, } Z = \frac{V}{I}$$

OR

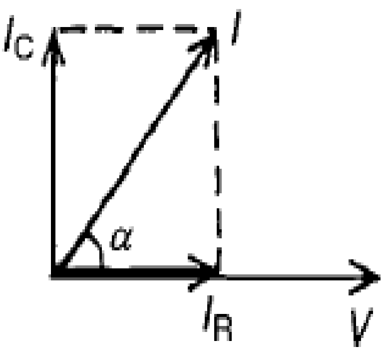
$$Z = \frac{(R)(X_L < 90°)}{R + jX_L}$$

ii. RC PARALLEL AC CIRCUIT

Circuit diagram



Phasor diagram



$$I = \sqrt{I_R^2 + I_C^2}$$

$$\tan \alpha = \frac{I_C}{I_R}$$

OR

$$I = I_R + jI_C$$

$$I_R = \frac{V}{R}$$

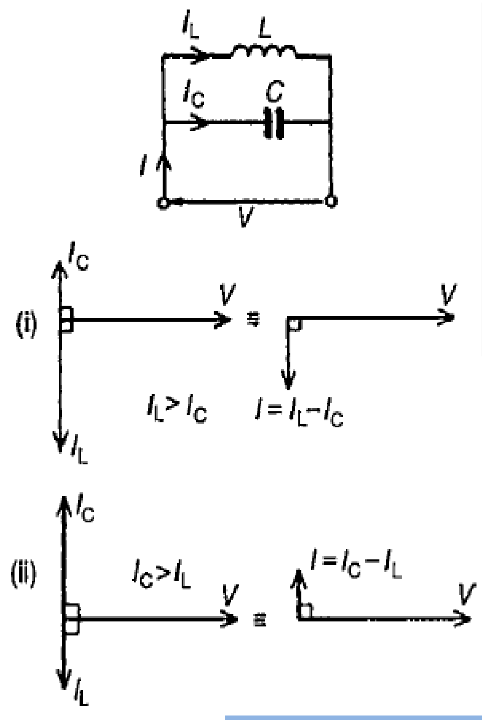
$$I_C = \frac{V}{X_C}$$

$$\text{Circuit impedance, } Z = \frac{V}{I}$$

OR

$$Z = \frac{(R)(X_C < -90°)}{R - jX_C}$$

iii. LC PARALLEL AC CIRCUIT



(i) $I_L > I_C$ (giving a supply current, $I = I_L - I_C$ lagging V by 90°)

(ii) $I_C > I_L$ (giving a supply current, $I = I_C - I_L$ leading V by 90°)

(iii) $I_L = I_C$ (giving a supply current, $I = 0$).

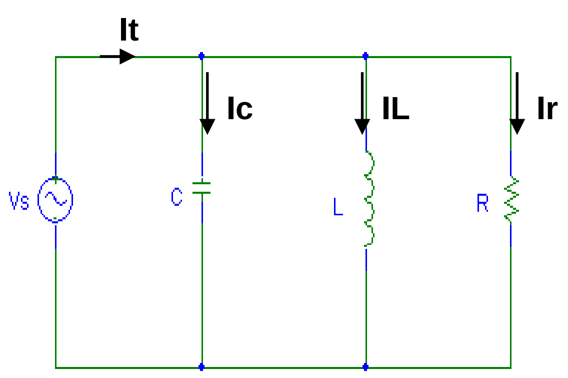
For the *L–C* parallel circuit,

$$I_L = \frac{V}{X_L} \quad I_C = \frac{V}{X_C}$$

I = phasor difference between I_L and I_C, and

$$Z = \frac{V}{I}$$

iv. R-L-C PARALLEL AC CIRCUIT

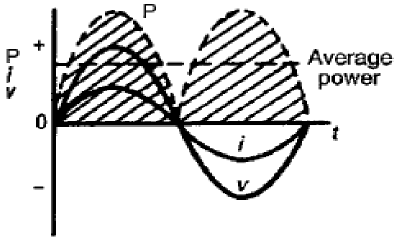


Circuit impedance, $Z = \frac{V}{I}$

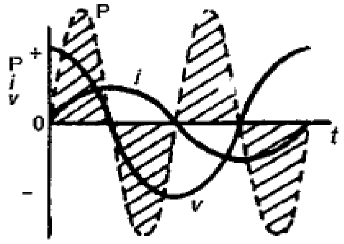
$$\frac{1}{Z} = \frac{1}{R\angle 0^\circ} + \frac{1}{X_L\angle 90^\circ} + \frac{1}{X_C\angle -90^\circ}$$

$I_C > I_L$	$I_L > I_C$
$I_T = \sqrt{I_R^2 + (I_C^2 - I_L)^2}$	$I_T = \sqrt{I_R^2 + (I_L^2 - I_C)^2}$
$\theta = Tan^{-1}\left(\frac{I_C - I_L}{I_R}\right)$	$\theta = Tan^{-1}\left(\frac{I_L - I_C}{I_R}\right)$

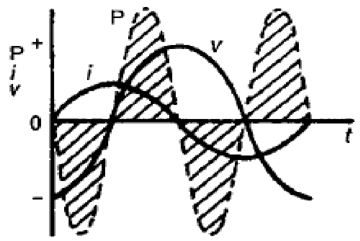
Power in pure resistance, inductance and capacitance



Pure resistance-average power = VI
(a)



Pure inductance-average power = 0
(b)



Pure capacitance-average power = 0
(c)

Power in R-L, R-C or R-L-C series

For an ***R–L***, ***R–C*** or ***R–L–C*** **series** a.c. circuit, the average power *P* is given by:

$$P = VI\cos\phi \text{ watts}$$

$$P = I^2 R \text{ watts}$$

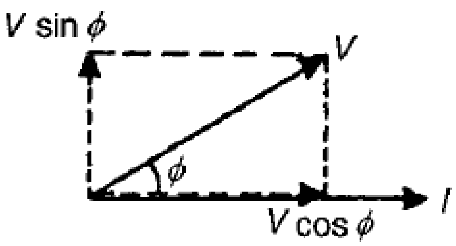
or

(V and I being r.m.s. values)

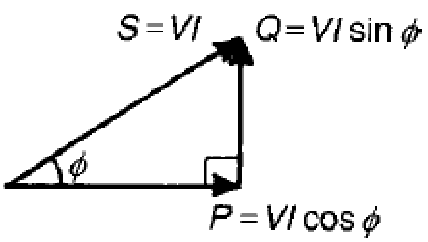
$$\cos\theta = \frac{R}{Z}$$ → **POWER FACTOR**

Power consumption in AC circuits

a. POWER TRIANGLE



(a) Phasor diagram



(b) Power triangle

Apparent power,

$$S = VI \text{ voltamperes (VA)}$$

True or active power,

$$P = VI\cos\phi \text{ watts (W)}$$

Reactive power,

$$Q = VI\sin\phi \text{ reactive voltamperes (var)}$$

$$\text{Power factor} = \frac{\text{True power } P}{\text{Apparent power } S}$$

POWER FACTOR

For sinusoidal voltages and currents,

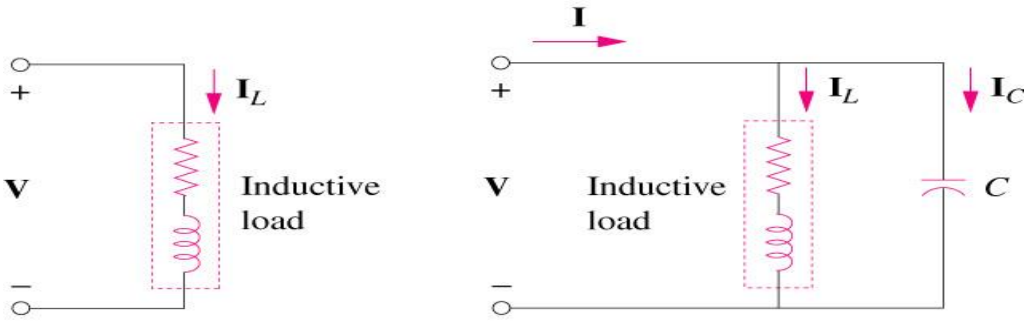
$$\text{power factor} = \frac{P}{S} = \frac{VI\cos\phi}{VI}$$

$$\cos\theta = \frac{R}{Z}$$ → **POWER FACTOR**

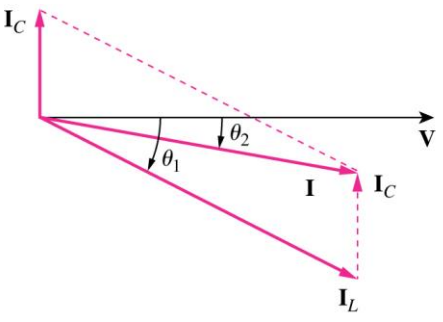
POWER FACTOR IMPROVEMENT

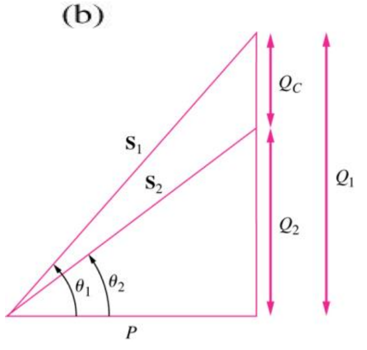
- ✓ The design of any power transmission system is very sensitive to the magnitude of the current in the lines as determined by the applied loads.
- ✓ Increased currents result in increased power losses (by a squared factor since $P = I^2R$) in the transmission lines due to the resistance of the lines.
- ✓ Heavier currents also require larger conductors, increasing the amount of copper needed for the system, and they require increased generating capacities by the utility company.
- ✓ Since the line voltage of a transmission system is fixed, the apparent power is directly related to the current level.
- ✓ In turn, the smaller the net apparent power, the smaller the current drawn from the supply. Minimum current is therefore drawn from a supply when $S = P$ and $Q_T = 0$.
- ✓ The process of introducing reactive elements to bring the power factor closer to unity is called **power-factor correction**. Since most loads are inductive, the process normally involves introducing elements with capacitive terminal characteristics having the sole purpose of improving the power factor.

Increasing the power factor without altering the voltage or current to the load is called Power Factor Correction



(a) (b)





Effect of capacitor on total current

Power triangle of power factor correction

WORK : Unit JOULE (J)

Work done or energy transferred when a force of 1 newton is exerted through a distance of 1m in the force direction.

ENERGY : Unit JOULE (J)

Ability to do work or capacity for doing work

***ONE WATT is the amount of power when 1Joule of energy is used in a second

POWER : Unit WATT (W)

The rate at which energy is used or rate of doing work

EFFICIENCY

Efficiency is the ratio of the output power delivered to a load to the input power to a circuit.

$$\text{Efficiency} = \frac{P_{OUT}}{P_{IN}}$$

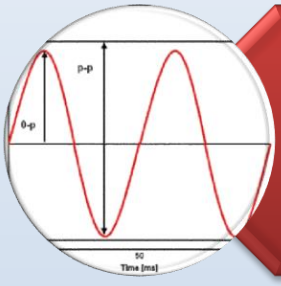
POWER LOSS

Internal power dissipation – operate power supply circuitry

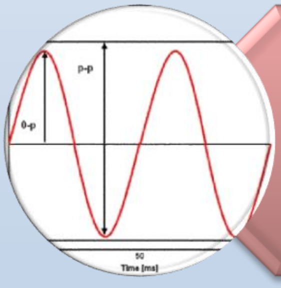
$$P_{OUT} = P_{IN} - P_{LOSS}$$

:- the higher efficiency = the lower power loss

Chapter 3: RESONANCE



Resonance in series and parallel circuits



Apply resonance in series and parallel circuits

What is resonance?

Resonance is a **phenomenon which occurred when reactance inductance value (XL) is equivalent with capacitance reactance value (XC).** That's mean resonance will **only occur in AC current's** circuit because only AC supply have frequency for XL & XC.

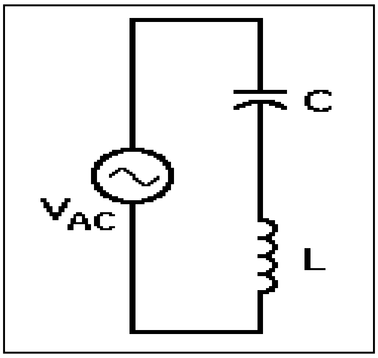
Resonance : XL = XC

There are two types of resonance:

- Resonance RLC series circuit
- Resonance RLC parallel circuit

A. Resonance RLC series circuit

Circuit here is LC series circuit with AC supply. Say that the frequency is changed until value of XL=XC.

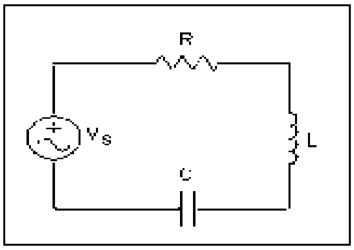


To happen **resonance : XL=XC**

Impedance, Z = jXL-jXC
= jXL-jXC
Z = 0

Circuit current, I = V / Z
= V / 0
= inf

Because Z=0, I=inf so this LC resonance circuit as if already short.



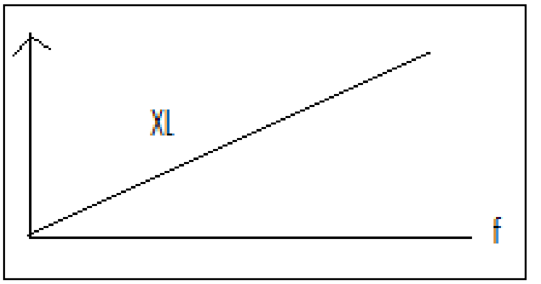
- RLC seriescircuit is practical circuit becaus e every L loop must be comprised internal resistance. So will be existing R in LC circuit practically.
- To study resonance phenomenon, frequency f need to be changed. Let see the behavior of circuit components on frequency, f which is resistor, inductor and capacitor.

Resistor, R

- Value of R, resistor are not depends on frequency, f.
- Addition or reduction of frequency do not change that R value.

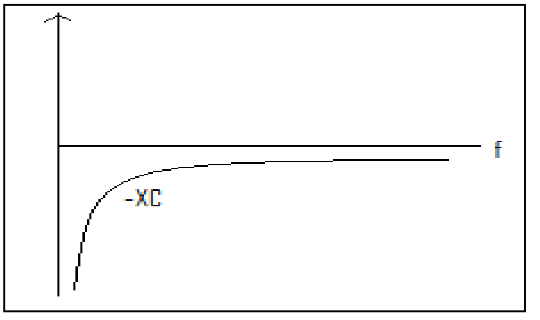
Inductor,L

- Current produce opposition that named inductive reactance(XL).
- **XL = 2πfL**
- From formula above found that XL is directly proportional with frequency, f.
- So graph of straightline through point 0 is achieved.



Capacitor, C

- Capacitor produce capacitive reactance (XC).
- **XC = 1/2πfC**
- So XC inversely proportional with f.
- Hyperbola graph in fourth quarter obtained because XC is -ve. **(-jXC)**



Resonance frequency, fr

To obtain resonance, XL=XC.

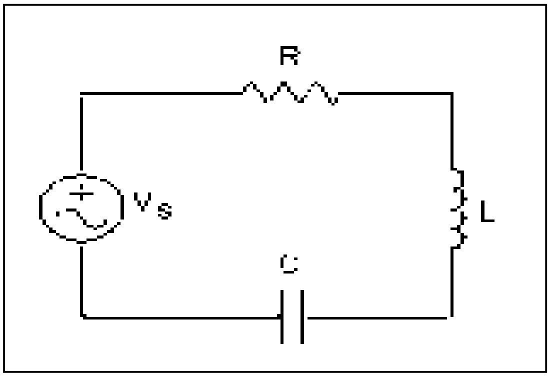
$2\pi frL = 1/2\pi frC$

$4\pi^2 fr^2 LC = 1$

$fr^2 = 1/4\pi^2 LC$

So, resonance frequency series is:

$$F_R = \frac{1}{2\pi\sqrt{LC}}$$

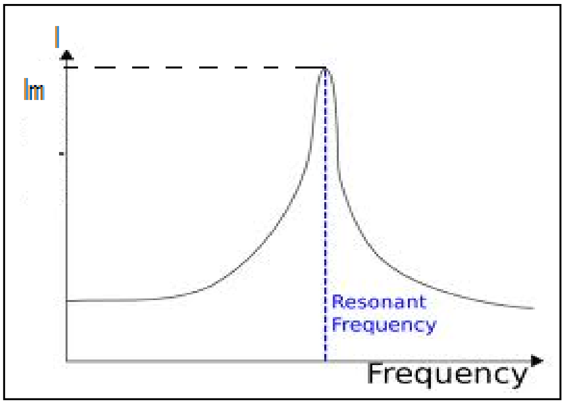


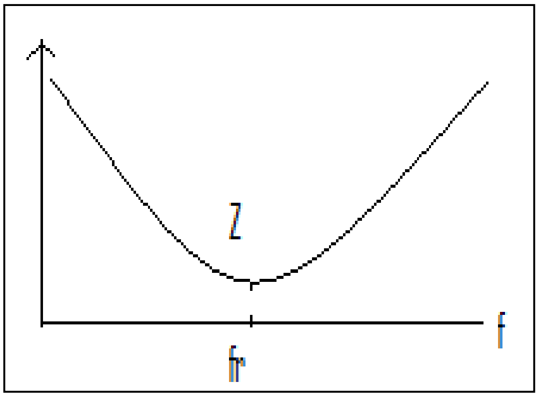
- XL = XC
- Z= R + j (XL-XC)
- Z= R + j (XL-XL)
- Z = R (min)

- I = V/Z
- Im = V/R (max)

- In resonance series RLC circuit, found that the impedence, Z is minimum on the other hand the current, I is maximum.
- When resenance happen, series RLC circuit become as resistive circuit (just R).
- So current and supply voltage are in phase.
- The power factor is uniti (1).

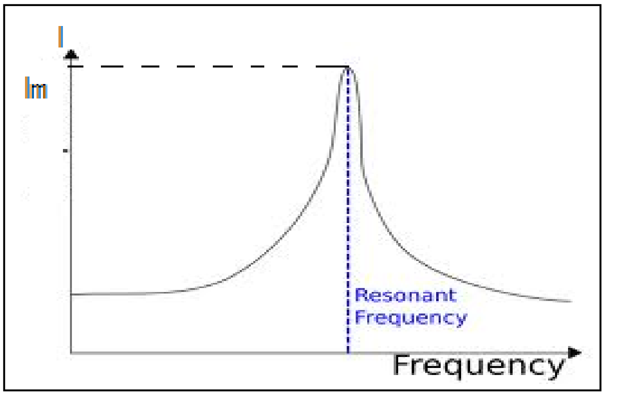
Resonance Graph





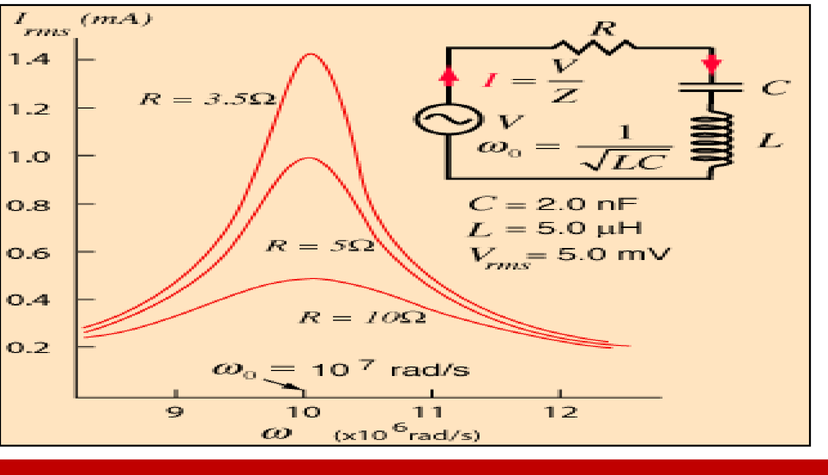
Graph Current (when resonance) vs frequency – resonance curve

Graph impedance vs frequency



- Commonly only current graph vs frequency during resonance only entailment.
- **Current graph vs this frequency is named "resonance curve"**

- This resonance shape of a curve depends on R obstruction value because only R component are limits current during resonant; Z=R, I=V / R.
- If R value is smaller, so resonance curve is sharper while R is larger, the curve is more horizontal.
- Curve that have more sharpness is better because it have nature high selectivity.
- The selectivity of a circuit is dependent upon the amount of resistance in the circuit. The variations on a series resonant circuit at below is an example in. The smaller the resistance, the higher the "Q" for given values of L and C.



Q-factor for resonance RLC Series circuit

- Definition: **Ratio between reactive power (**inductive and capacitive) in resonance to real power.
- **Q factor** that enable circuit is risen by using loop that have inductor value(L) that high but internal resistor value that low.

$$Q = \frac{VAR}{Watt} = \frac{I^2 XL}{I^2 R} = \frac{XL}{R}$$

$$Q = \frac{2\pi f L}{R}$$

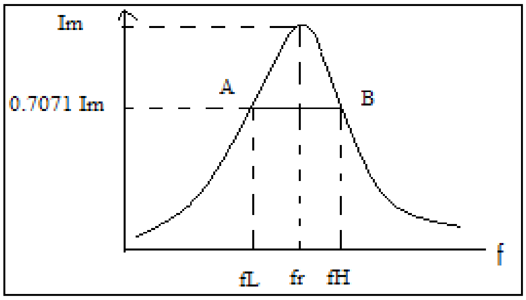
$$\text{But for } Af_r = \frac{1}{2\pi\sqrt{LC}}$$

$$Q = \frac{2\pi\left(1/_{2\pi}\sqrt{LC}\right)L}{R} = \frac{1}{R\sqrt{LC}} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Bandwidth , Bw

- Definition: **Differences between two point when the power are half of maximum power**.
- Distance between A and B is called bandwidth, Bw
- Power when resonance , $\mathbf{Pm = Im^2R}$
- Power at A and B :

$$P = \left(\frac{I_m}{\sqrt{2}}\right)^2 R = \frac{I_m{}^2 R}{2} = 1/_2\, P_{max}$$



- AB is called "half point maximum power".

Where, fL – low frequency

fH – high frequency

fr – resonance frequency

Bandwidth **, Bw = fH – fL** Hz

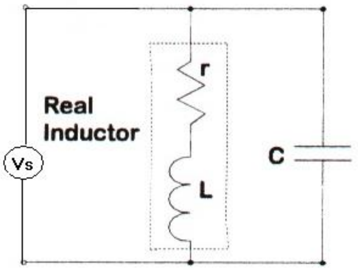
f_r *is in the middle between* f_L *and* f_H. Formula $\boldsymbol{B_w} = \frac{f_r}{Q}$ **Hz**

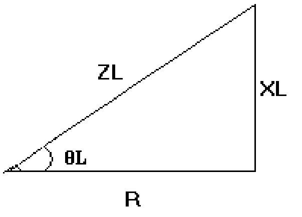
$from\ Q = \frac{2\pi f_r}{(R)}$, Replace in $\boldsymbol{B_w}$: $\boldsymbol{B_w} = \frac{f_r}{(2\pi f_r{}^{L}/_{R})}$

$$\boldsymbol{B_w} = \frac{R}{2\pi L} \textbf{ Hz}$$

Parallel Resonance

- In parallel resonant circuit, we will take into account practical inductor which contains internal resistance R, connected parallel to C capacitor to generate RLC parallel circuit. This parallel circuit alleged staying in resonance state when the reactive component current became zero.





- Component reactive current= Ic-IL sinθL
- To happen resonance, the reactive component value current is zero
- Ic – IL sin θL =0

Ic = IL sin θL ------------1

- From impedance triangle ,

sin θL = XL/ZL , IL=V/ZL -----------2

IcXc = Vc

Ic = Vc/Xc ------------3

When resonance occur, the reactive component value current is zero.

$$I_C - I_L sin\theta_L$$

From the impendance triangle, $\sin\,\theta_L = \frac{X_L}{Z_L}, I_L = \frac{V}{Z_L}$,

$$I_C = \frac{V_C}{X_C}$$

Substitute : $\frac{V}{X_C} = \frac{V}{Z_L}\sin\,\theta L$

$$\frac{V}{X_C} = \frac{V}{Z_L} \times \frac{XL}{ZL} = \frac{VXL}{ZL^2}$$

$ZL^2 = XL \times XC = 2\pi f L \times \frac{1}{2}\pi f C$, $\qquad ZL^2 = \frac{L}{C}$

$\frac{L}{C} = R^2 + XL^2$, $[ZL^2 = R^2 + XL^2]$

$$\frac{L}{C} = R^2 + (2\pi f L)^2$$

So, ther resonance frequency is $f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$

• If the internal resistance R is neglected, R = 0Ω, so the resonance frequency will be:

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - 0}$$
$$= \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

$f_r = \frac{1}{2\pi\sqrt{LC}}$ Hz when R = 0Ω

Impedance of Parallel Resonance

From the vector diagram, if the component reactive current is zero, the circuit current , $I_T = I_L \cos\theta L$,

$I_T = \frac{V}{ZT}$ = $I_L \cos\theta L$, $\cos\theta L = \frac{R}{ZL}$, where ZT is an impedance

$= \frac{V}{ZL} \times \frac{R}{ZL}$

= $\frac{VR}{ZL^2}$, where $ZL^2 = \frac{L}{C}$

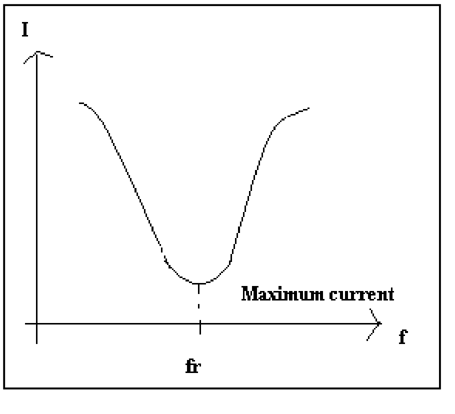
= $\frac{VR}{(L/C)}$

Substitute $I_T = \frac{V}{ZT}$ and I_T = $\frac{VR}{(L/C)}$,

$$\frac{V}{ZT} = \frac{VR}{(L/C)}$$
$$ZT = \frac{L}{CR}$$ (CR is dynamic Impedance)

- Found that in parallel resonance circuit, dynamic impedance is maximum while the current is minimum. This is opposite with impedance and current in serial resonance.

- Graf Current Vs Frequency (Curve Resonance)



Q factor for parallel Resonance

- Definition : **current ratio in capacitance to current in circuit**

$$Q = \frac{I_C}{I_T}$$

$$Q = \frac{\left(V/X_C\right)}{V/_{L/CR}} = \frac{2\pi f L}{R}$$

Dissipation Factor

- Definition: In physics, the **dissipation factor** (DF) is a measure of loss-rate of power of a mode of oscillation (mechanical, electrical, or electromechanical) in a dissipative system. It is the reciprocal of **Quality factor, which represents the quality of oscillation.**

$$DF = \frac{1}{Q}$$

TEST-MIND!!!

1. One choke with 0.5H inductor and internal resistor 10Ω connected series with capacitor 40μF. The voltage is 200v. Calculate,
   a. Maximum current
   b. Resonance frequency
   c. Q factor
   d. Potential difference across inductor and capacitor

2. One circuit with internal resistor 20Ω dan inductor 0.55H connected parallel with capacitor 55μF. This circuit is connected to a supply of 100v with variable frequency. Calculate :
   a. resonance frequency
   b. current circuit
   c.Q factor

Chapter 4: TRANSFORMER


Types of transformer


Non-ideal transformer


Construction and the operation of a transformer


Transformer increases and decreases voltage

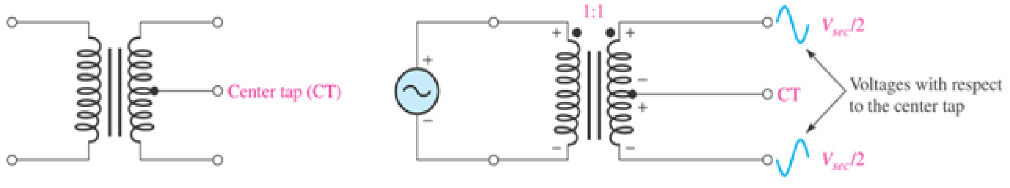

The effect of a resistive load across the secondary winding

Type of transformer

- Center tapped transformer
- Multiple winding transformer
- Auto transformer

A. CENTER TAPPED TRANSFORMER

- The center tap (CT) transformer is equivalent to two secondary windings with half the voltage across each
- Center tap windings are used for rectifier supplies and impedance-matching transformers

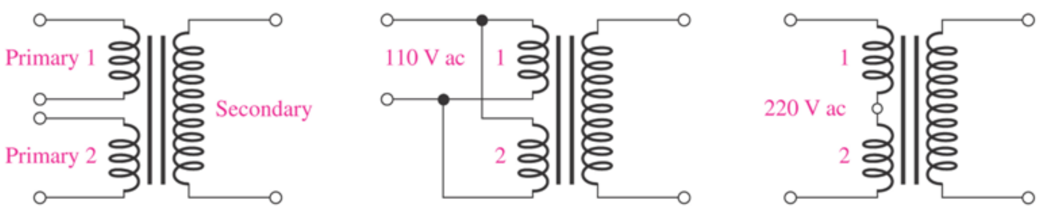


(a) Center-tapped transformer

(b) Output voltages with respect to the center tap are 180° out of phase with each other and are one-half the magnitude of the secondary voltage.

B. MULTIPLE WINDING TRANSFORMER

- Multiple-winding transformers have more than one winding on a common core. They are used to operate on, or provide, different operating voltages



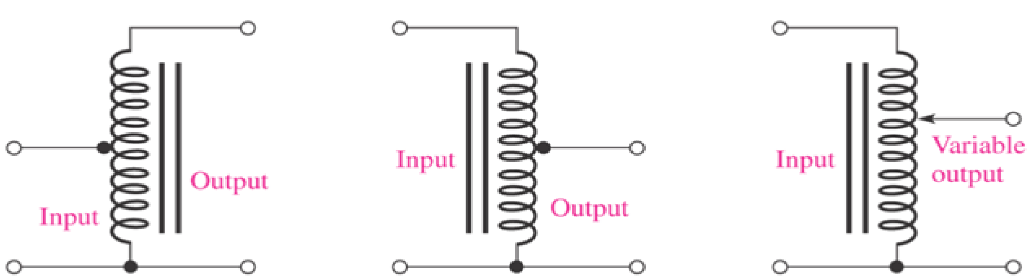
(a) Two primary windings

(b) Primary windings in parallel for 110 V ac operation

(c) Primary windings in series for 220 V ac operation

C. AUTO TRANSFORMER

- In an autotransformer, one winding serves as both the primary and the secondary. The winding is tapped at the proper points to achieve the desired turns ratio for stepping up or down the voltage



(a) Step-up

(b) Step-down

(c) Variable

None-ideal Tansformer

- An ideal transformer has no power loss; all power applied to the primary is all delivered to the load. Actual transformers depart from this ideal model. Some loss mechanisms are:
  i. Winding resistance
  ii. Hysteresis loss
  iii. Core losses
  iv. Flux leakage
  v. Winding capacitance
- The ideal transformer does not dissipate power. Power delivered from the source is passed on to the load by the transformer.
- The efficiency of a transformer is the ratio of power delivered to the load (*Pout*) to the power delivered to the primary (*Pin*).

Ideal Transformer : Power Equation

- If the secondary coil is attached to a load that allows current to flow, electrical power is transmitted from the primary circuit to the secondary circuit.
- Ideally, the transformer is perfectly efficient; all the incoming energy is transformed from the primary circuit to the magnetic field and into the secondary circuit. If this condition is met, the incoming electric power must equal the outgoing power:-

$$P_{\text{incoming}} = I_p V_p = P_{\text{outgoing}} = I_s V_s$$

- Giving the ideal transformer equation:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

- Transformers normally have high efficiency, so this formula is a reasonable approximation.
- For an ideal transformer, the $P_{Primary}$ is equal to the $P_{Secondary}$, or the **power input is equal to the power output**.

$$\mathbf{P_{out} = P_{in}}$$
$$\mathbf{V_s I_s = V_p I_p}$$
$$\mathbf{I_s / I_p = V_p / V_s}$$

- Efficiency of transformer:

$$P_{out} = P_{in} \times \text{Efficiency Rating}$$

η = Pout / Pin = Pout / (Pout+ losses)

$$\eta = \frac{VsIs \times P.F}{(VsIs \times P.F) + \text{copper loss} + \text{core loss}}$$

Ideal Transformer : Power Loss

- A practical transformer differs from the ideal transformer in many respects.
- The practical transformer has:-
  i. iron or core losses
  ii. copper losses.
- **Iron or core losses -** eddy current and hysterisis losses
- **copper losses -** in the resistance of the windings

Iron or core losses

• The magnitude of these losses is quite small. This losses due to eddy current and hysteresis loss in it.

Copper losses

•Is the energy loss in the windings when the transformer is loaded.

Total copper loss, $P_c = I_p^2R_p + I_s^2R_s$

Iron or core losses

Eddy Current

- The magnetic core of a transformer consists of many laminations of a high-grade silicon steel.
- When the alternating flux cuts the steel core, an emf is induced in each lamination, causing a current (eddy current) to flow in the closed electrical.
- Due to this eddy current and resistance in each lamination, a certain amount of power will be absorbed, producing heat in each lamination and also in the core.

Hysteresis

- The alternating flux causes changes in the alignment of the molecules in the magnetic cores.
- The change is energy consuming and heat is produced within the core.
- The energy loss is referred to as hysteresis loss, the degree of loss being dependent on the material used .

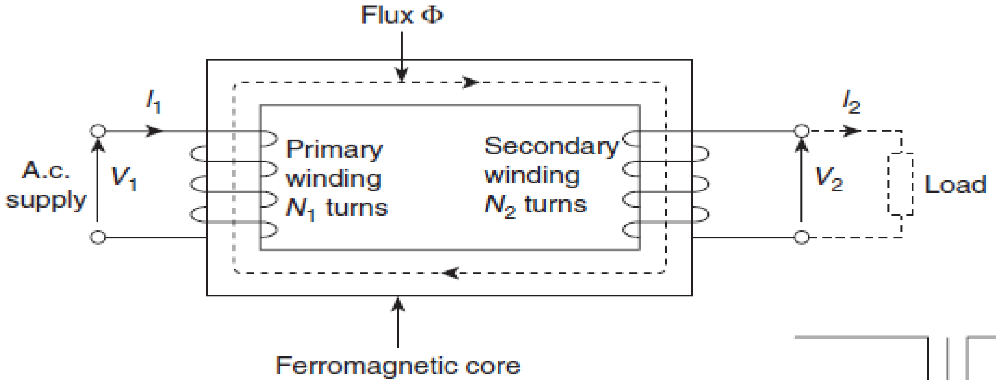
None-ideal Transformer : Power Loss

Total losses in transformer is the summation of core/iron losses and copper losses

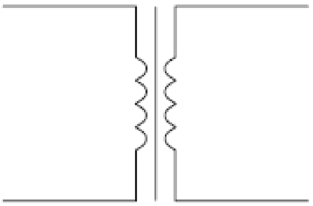
- Total transformer losses, $P_T = I_p^2R_p + I_s^2R_s$ **+core losses**

Basic Transformer

- Source voltage is applied to the primary winding
- The load is connected to the secondary winding
- The core provided a physical structure for placement of windings and a magnetic path so that the magnetic flux lines are concentrated close to the coils
- Typical core materials are : air, ferrite and iron

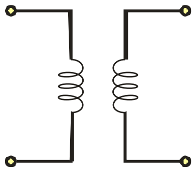


- A transformer is a device which uses the phenomenon of mutual induction to change the values of alternating voltages and currents.

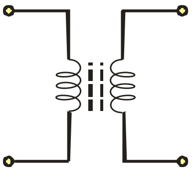


Circuit diagram

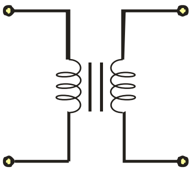
- The basic transformer is formed from two coils that are usually wound on a common core to provide a path for the magnetic field lines. Schematic symbols indicate the type of core.



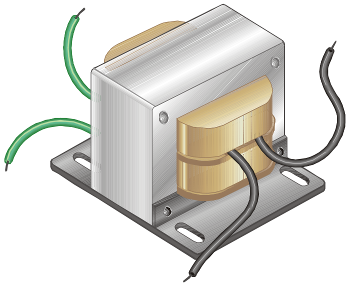
Air core



Ferrite core

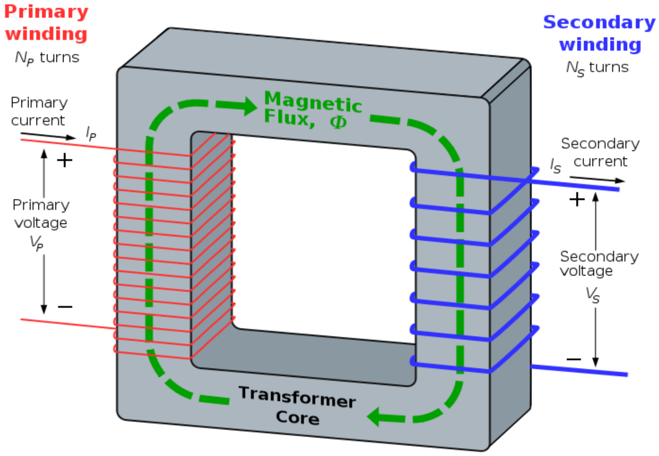


Iron core



Small power transformer

The parts of an ideal transformer



Transformer principles

- The transformer is based on two principles:
  i. first, that an electric current can produce a magnetic field (electromagnetism), and
  ii. second that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction).
- Changing the current in the primary coil changes the magnetic flux that is developed.
- The changing magnetic flux induces a voltage in the secondary coil.
- Current passing through the primary coil creates a magnetic field.
- The primary and secondary coils are wrapped around a core of very high magnetic permeability, such as iron, so that most of the magnetic flux passes through both the primary and secondary coils.

Transformer : Operation principles

- Transformer action: based on the laws of electromagnetic induction.
- There is no electrical connection between the primary and secondary. The AC power is transferred from primary to secondary through magnetic flux.
- If an ac voltage is applied to the primary coil, magnetic flux will be created.
- When the magnitude of the applied flux changed, then the generated flux changed.
- This changing flux will link the primary and secondary coil and induce a voltage across the secondary windings.
- There is no change in frequency (output power has the same frequency as the input power).

INDUCTION LAW

- The voltage induced across the secondary coil may be calculated from Faraday's law of induction, which states that:

$$V_s = N_s \frac{d\Phi}{dt}$$

where *V*s is the instantaneous voltage, *N*s is the number of turns in the secondary coil and Φ is the magnetic flux through one turn of the coil.

- Since the same magnetic flux passes through both the primary and secondary coils in an ideal transformer, the instantaneous voltage across the primary winding equals:

$$V_p = N_p \frac{d\Phi}{dt}$$

- Taking the ratio of the two equations for *V*s and *V*p gives the basic equation for stepping up or stepping down the voltage

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

- A useful parameter for ideal transformers is the turns ratio defined as:

$$n = \frac{N_{sec}}{N_{pri}}$$

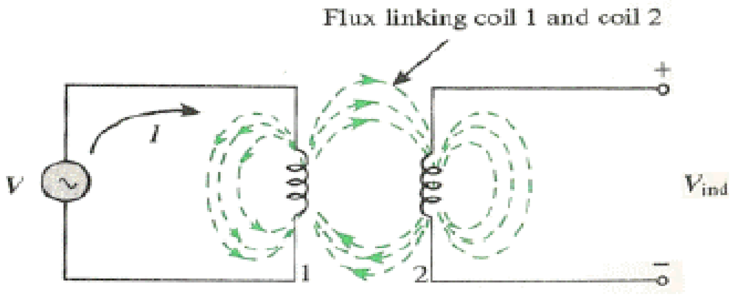
where N_{sec} = number of secondary windings

N_{pri} = number of secondary windings

- Most transformers are not marked with turns ratio, however it is a useful parameter for understanding transformer operation.

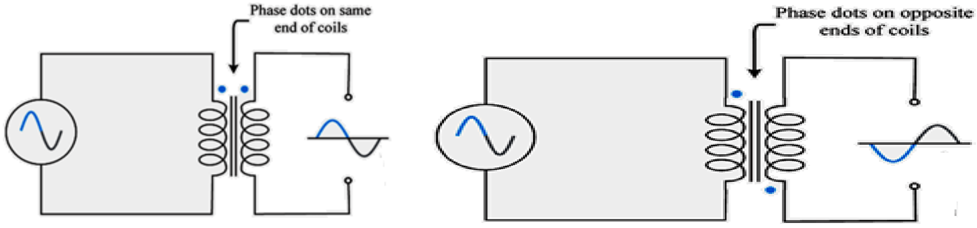
Function of a transformer

- To transfer current, voltage and power from one series of windings (coils) to another.



Transformer construction

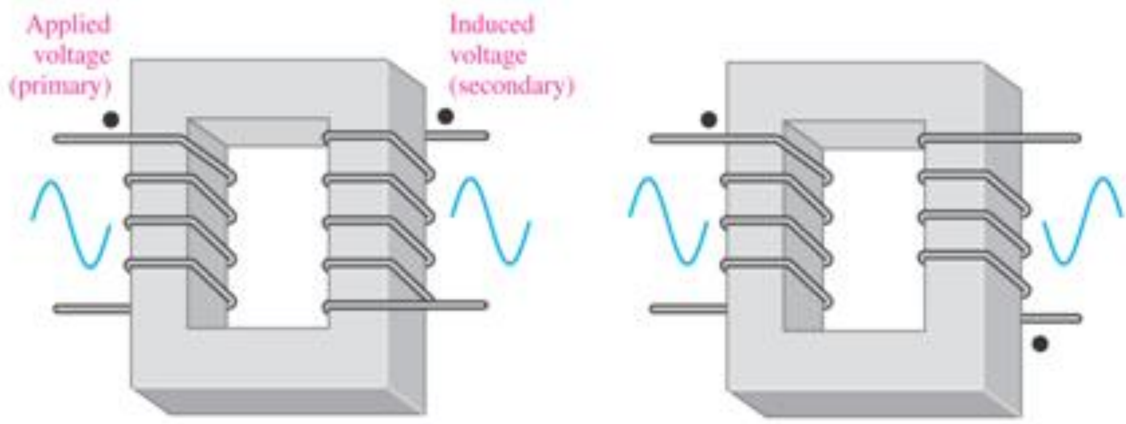
- The transformer consists of core, surrounded by at least two series of coils.
- The core is used as to aid in linking the flux from the primary coil to the secondary coil.
- From the principle of mutual induction, when two coils are inductively coupled and if the current in one coil is change uniformly, an emf (electromagnetic force) is induced in the other coil.
- If a closed path is provided at the secondary circuit, this induced emf at the secondary drives a current.
- Dots are used in diagrams of transformers to indicate the current polarities for the windings.
- Dotted terminals have the same polarity.



(a) Voltage are in phase (b) Voltage are out of phase

Transformer : Direction of windings

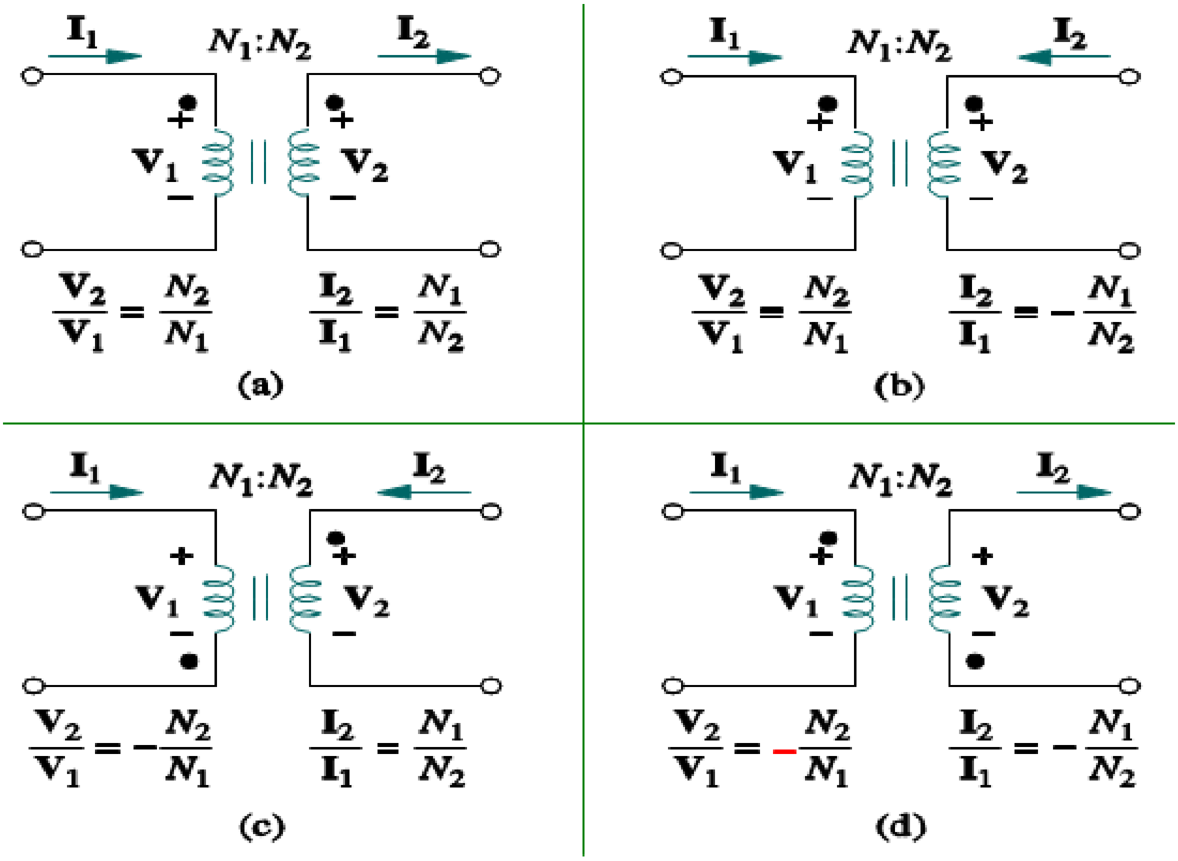
- The direction of the windings determines the polarity of the voltage across the secondary winding with respect to the voltage across the primary
- Phase dots are used to indicate polarities



(a) The primary and secondary voltages are in phase when the windings are in the same effective direction around the magnetic path.

(b) The primary and secondary voltages are 180° out of phase when the windings are in the opposite direction.

- Typical circuits illustrating polarity for voltages and direction of currents of an ideal transformer



(a) $\frac{V_2}{V_1} = \frac{N_2}{N_1}$, $\frac{I_2}{I_1} = \frac{N_1}{N_2}$

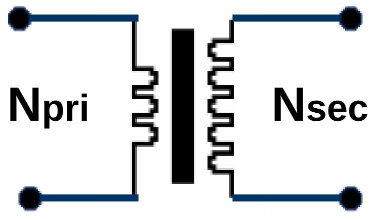
(b) $\frac{V_2}{V_1} = \frac{N_2}{N_1}$, $\frac{I_2}{I_1} = -\frac{N_1}{N_2}$

(c) $\frac{V_2}{V_1} = -\frac{N_2}{N_1}$, $\frac{I_2}{I_1} = \frac{N_1}{N_2}$

(d) $\frac{V_2}{V_1} = -\frac{N_2}{N_1}$, $\frac{I_2}{I_1} = -\frac{N_1}{N_2}$

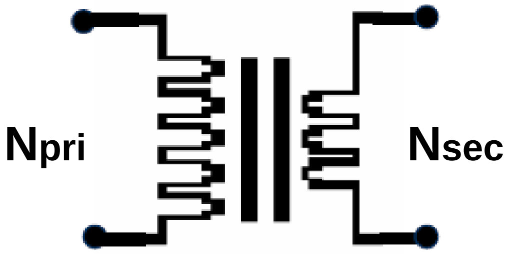
Step-up Transformer

- A transformer that has **more turns on the secondary than the primary side** of transformer will **increase the input voltage**.
  - Nsec > Npri
  - ŋ > 1
  - Symbol



Step-Down Transformer

- A transformer that has **more turns on the primary than the secondary side** of the transformer will **decrease the input voltage.**
  - Nsec < Npri
  - ŋ < 1
  - Symbol



Transformer as an isolation device

- Transformer is useful in providing electrical isolation between the primary circuit and the secondary circuit because is no electrical connection between the two windings
- In a transformer, energy is transferred entirely by magnetic coupling
- A transformer does not pass dc, therefore a transformer can be used to keep the dc voltage on the output of an amplifier stage from affecting the bias of the next amplifier
- The ac signal is coupled through the transformer between amplifier stages

EMF Equation of a Transformer

The rms value of induced emf in primary and secondary winding is given by:

$$E_p = 4.44 f N_p a B$$
$$E_S = 4.44 f N_S a B$$

where: E is the sinusoidal root mean square voltage of the winding

f is the frequency in hertz

N is the number of turns of wire

a is the cross-sectional area of the core

B is the peak magnetic flux density in tesla. The value 4.44 collects a number of constants required by the system of units.

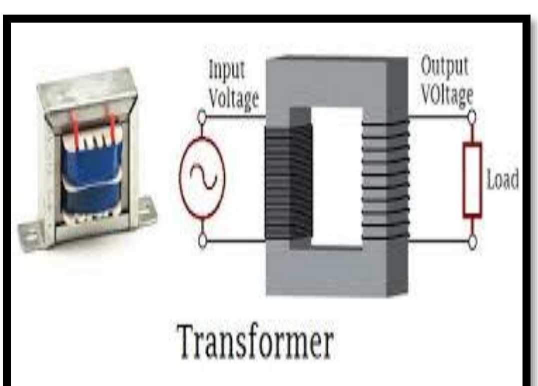
Where B = Ø / A

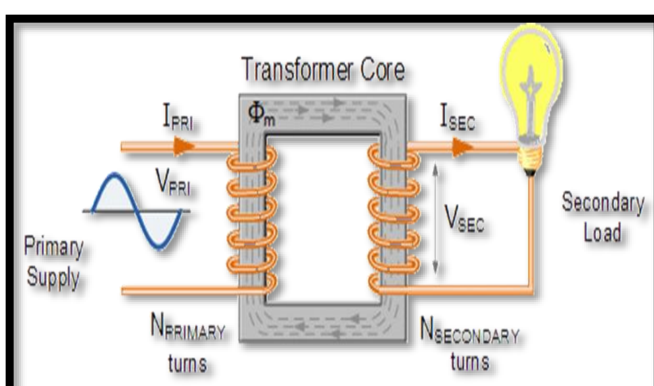
Aplication of Transformer

- Step-up or step-down voltage and current.
- Isolation device electrical isolation. Electrical isolation can be used to improve the safety of electrical equipment.
- DC isolation. Coupling transformers can be used to block DC signals from reaching the secondary circuit.
- Impedance matching for max power transfer

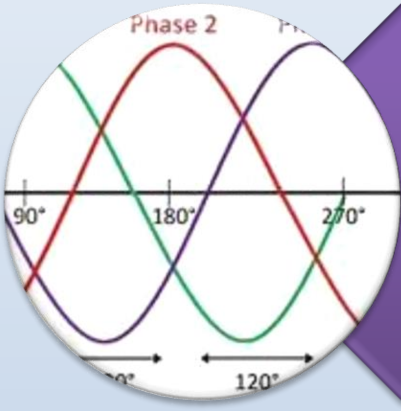
Special Transformer

- **Autotransformers**
  - Use in low-voltage applications since has only one winding.
- **Induction Circuit Breaker**
  - Use to shut off the current in a circuit, thus prevent fires cause by a short in an electrical device.
- **Lighting Ballast**
  - Use to start the lamp by producing the necessary voltage and limits current thro the lamp.
- **Coupling Transformer**
  - Isolates each section of the amplifier – so individual amplifier characteristics will not interfere with others

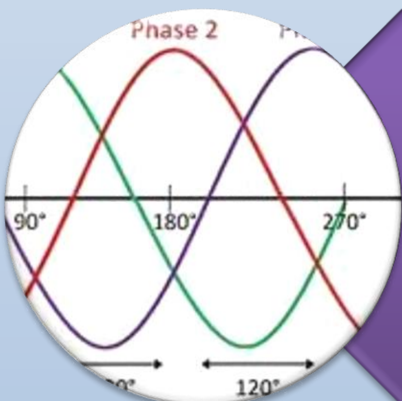




Chapter 5: THREE PHASE SYSTEM



Three phase system principle



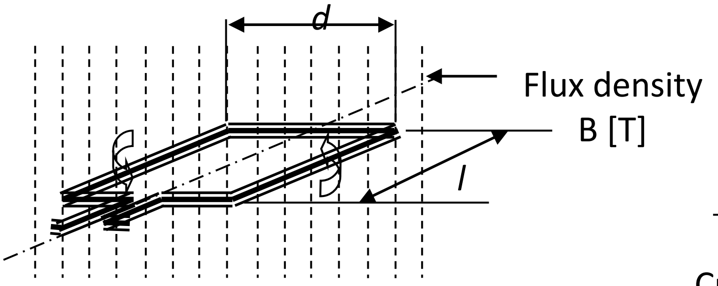
Three phase system configurations

Introduction of Three Phase System

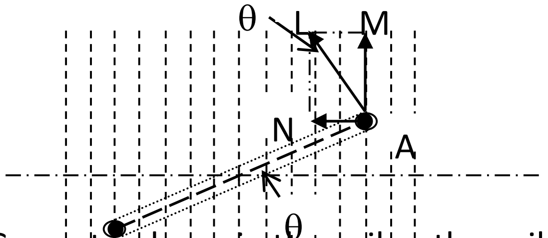
- Three-phase electricity supply is a common way of transmission of alternating current electricity supply.
- It is a multi-phase systems, and is the most commonly used in electrical distribution grid system in the world. It is also used as a source of power for large electric motors and other high load.
- In general, three-phase system is the most economical system as it uses less conductor material to transmit electricity from the system single-phase or two phases are equal at the same voltage.
- In the three-phase system, three conductors carry three alternating current that reached peak values at different times, with intervals between the phases of 1 / 3 cycle.
- A three phase ac power systems consists of three phase generators, transmission lines and load
- A three phase generator consists of three single phase generators, with voltages equal in magnitude but differing in phase angle from the others by 120°

Generation of Three Phase System

- A 3-phase generator consists of 3 single phase generators, with voltages equal in magnitude but differing in phase angle from the others by 120°
- Rotating at a constant speed in a uniform magnetic field.
- Each voltage source is called phase.
- Usually, three phases are labeled as
  - i. Red (R-Red)
  - ii. Yellow (Y-Yellow)
  - iii. Blue (B-Blue).

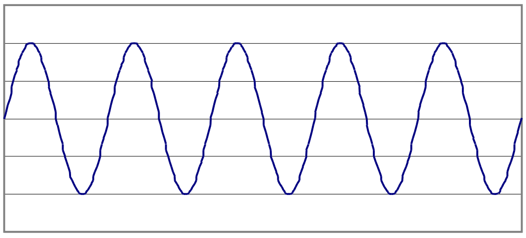


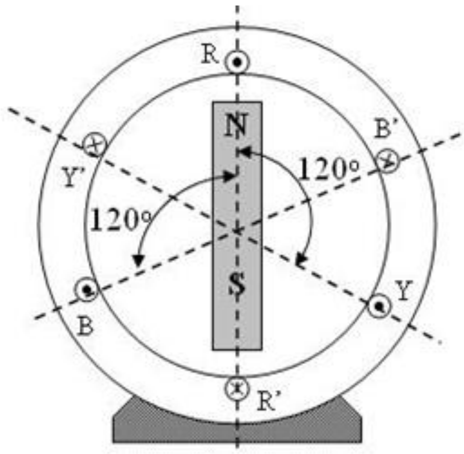
Generator for single phase

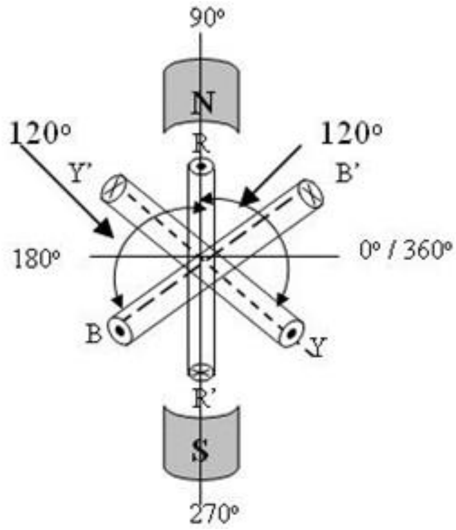


Current induces in the coil as the coil moves in the magnetic field

Note
Induction motor cannot start by itself. This problem is solved by introducing three phase system







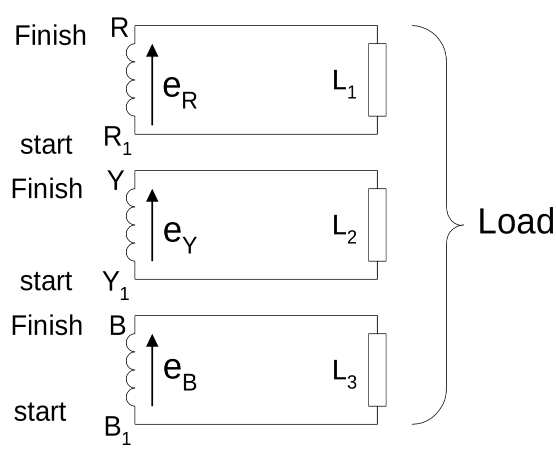
- Instead of using one coil only , three coils are used arranged in one axis with orientation of 120° each other. The coils are R-R1 , Y-Y1 and B-B1. The phases are measured in this sequence R-Y-B. i.e Y lags R by 120° , B lags Y by 120°.

- The three winding can be represented by the above circuit. In this case we have six wires. The emf are represented by e_R , e_Y, e_B.

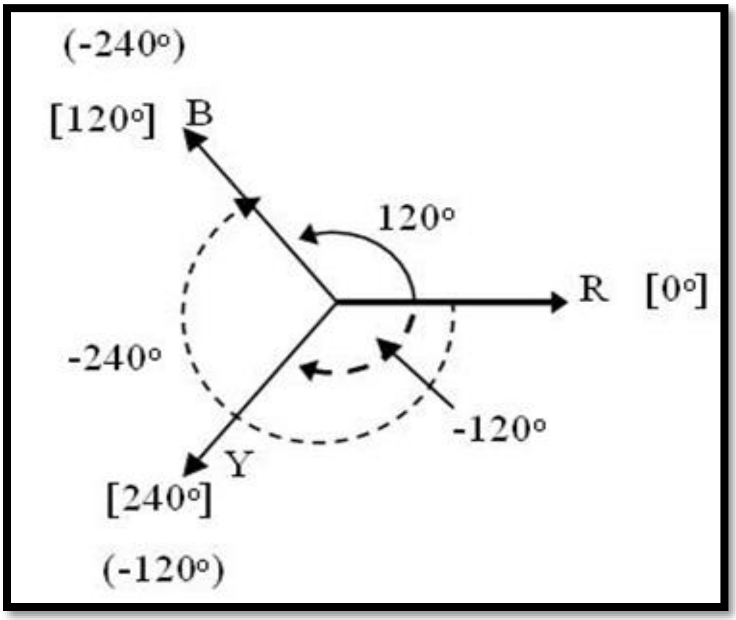
$$e_R = E_m \sin \omega t$$

$$e_Y = E_m \sin(\omega t\text{-}120^\circ)$$

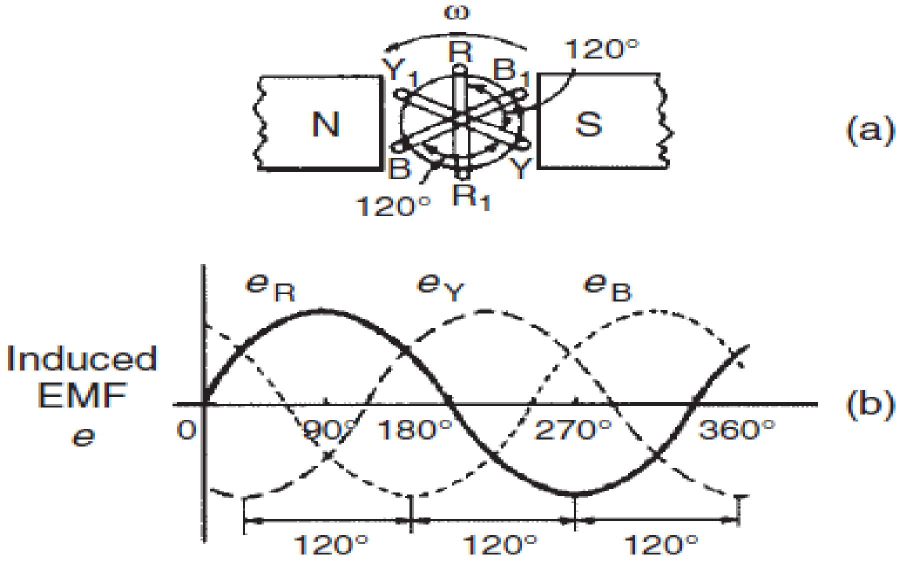
$$e_B = E_m \sin(\omega t\text{-}240^\circ)$$



Vector diagram for three-phase system

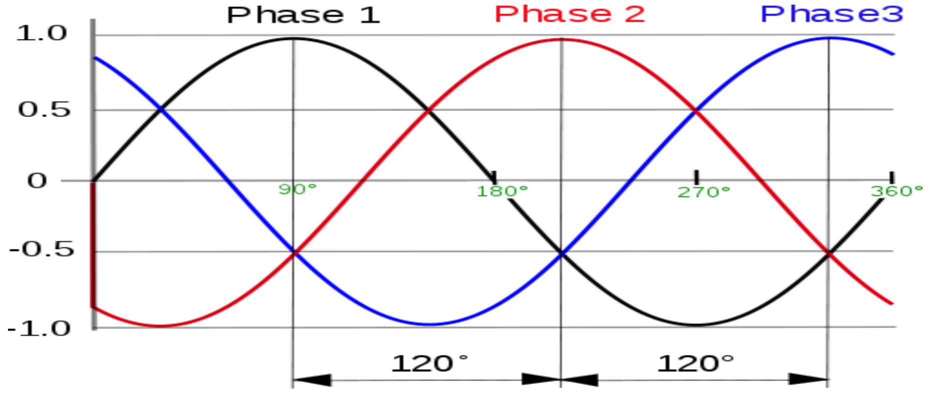


Three Phase System : EMF waveform



Three Phase System : Phase Sequence

Definition :- The order in which the voltages in the three phases reach their maximum values



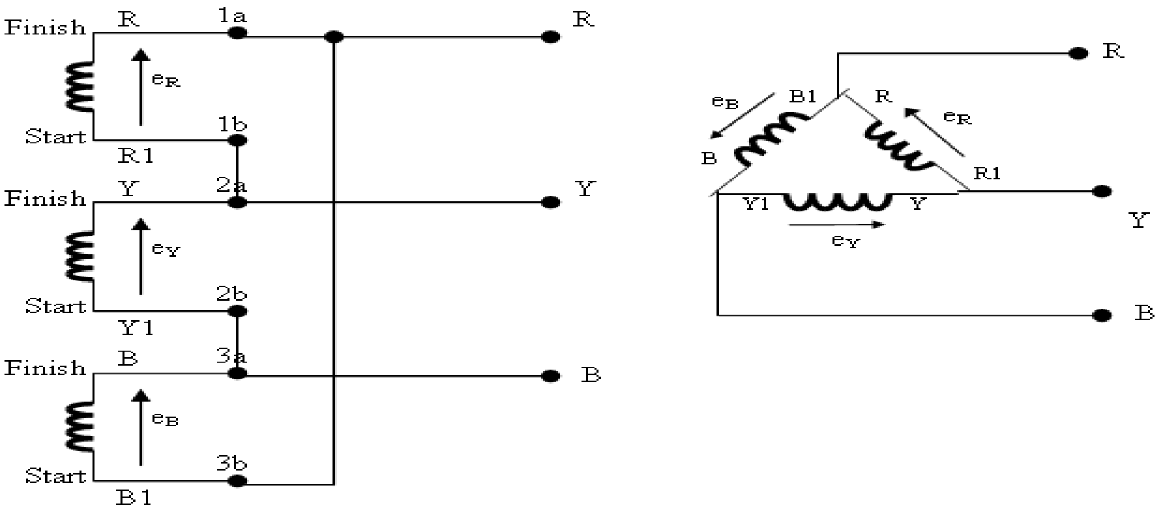
- The voltage between any one line and natural is called the phase voltage (VPH)
- The current flowing in a phase is known as the current phase (IPH)
- The voltage between any two lines or phases is called the line voltage (VL)
- The current flowing in a line is called the line current (IL)

Three Phase System : Phase and Line Element

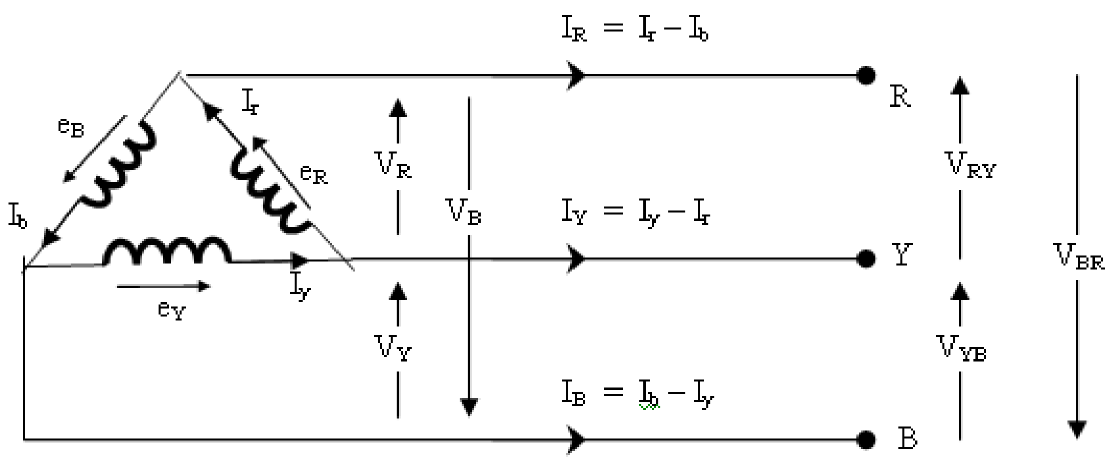
- The voltage between any one line and natural is called the phase voltage (VPH)
- The current flowing in a phase is known as the current phase (IPH)
- The voltage between any two lines or phases is called the line voltage (VL)
- The current flowing in a line is called the line current (IL)

Three Phase System Construction

DELTA Connection



a) Physical connection diagram



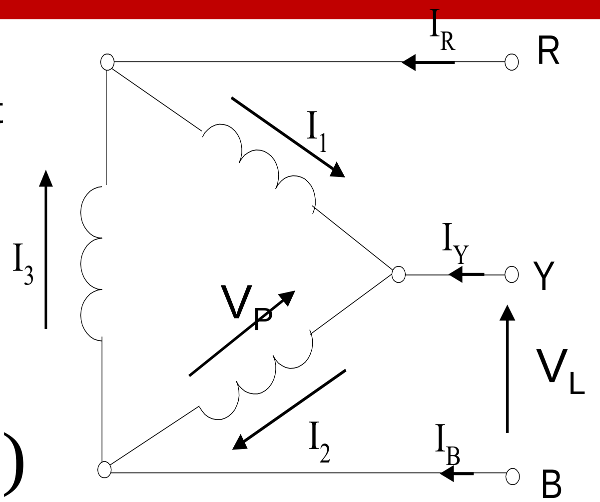
Phase voltage (V_{PH}) : V_R, V_Y, V_B

Phase current (I_{PH}) : I_r, I_y, I_b

Line voltage (V_L) : V_{RY}, V_{YB}, V_{BR}

Line current (I_L) : I_R, I_Y, I_B

- I_R, I_Y and I_B are called line current
- I_1, I_2 and I_3 are called phase current



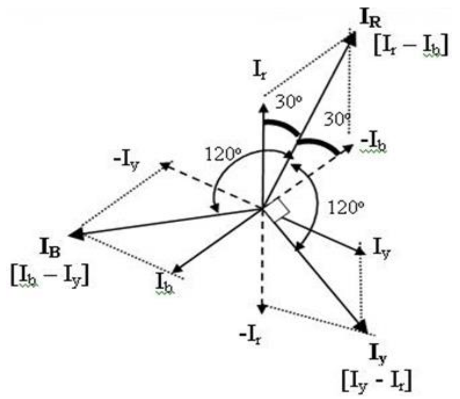
From Kirchoff current law we have:

$$I_R = I_1 - I_3 = I_1 + (-I_3)$$

$$I_Y = I_2 - I_1 = I_2 + (-I_1)$$

$$I_B = I_3 - I_2 = I_3 + (-I_2)$$

In phasor diagram



Since the loads are balanced, the magnitude of currents are equaled but 120° out of phase. i.e $I_1 = I_2 = I_3 = I_P$ Therefore:-

$$I_R = I_1\angle 30°;$$

$$I_Y = I_2\angle -90°;$$

$$I_B = I_3\angle 150°;$$

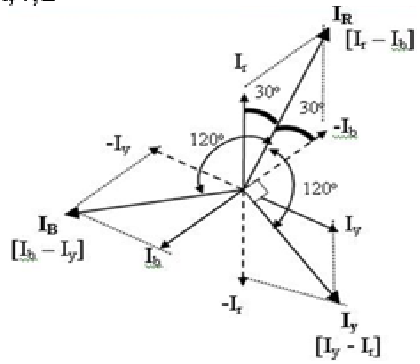
Where $I_{1,2,3}$ is a phase current and $I_{R,Y,B}$ is a line current

$$I_R = 2I_1 \cos 30^\circ = (\sqrt{3})I_P$$

$$I_Y = 2I_2 \cos 30^\circ = (\sqrt{3})I_P$$

$$I_B = 2I_3 \cos 30^\circ = (\sqrt{3})I_P$$

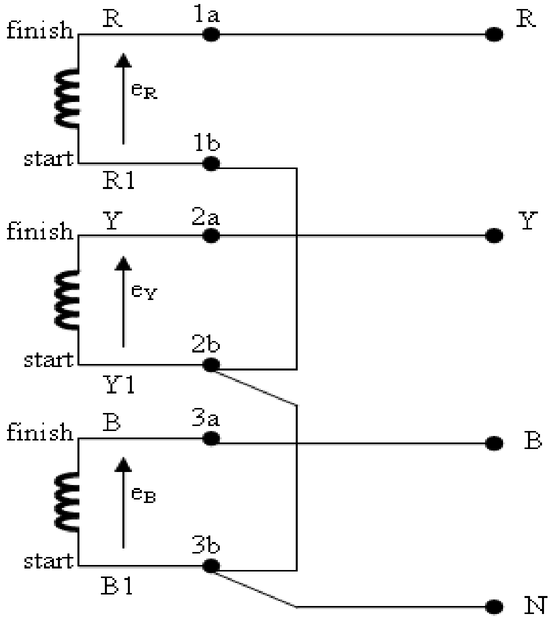
Thus $I_R, I_Y, I_B = I_L$



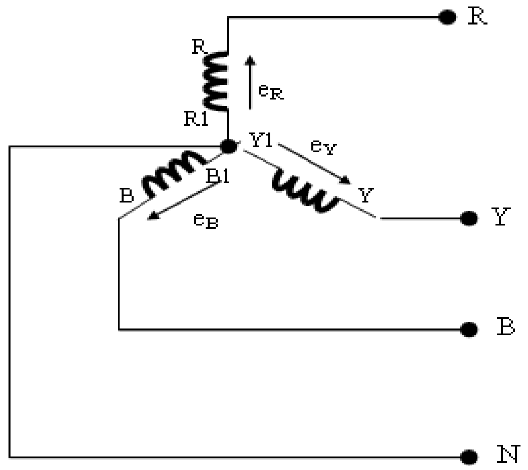
$$V_L = V_P$$

$$I_L = (\sqrt{3})I_P$$

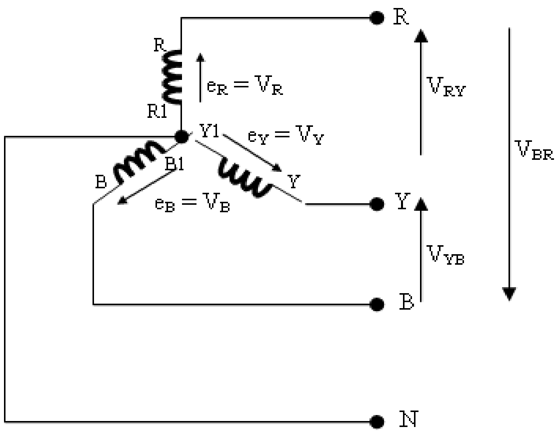
STAR Connection



a) Physical connection diagram



b) Conventional connection diagram



Phase voltage (V_{PH}) : V_R, V_Y, V_B
@ V_{RN}, V_{YN}, V_{BN}

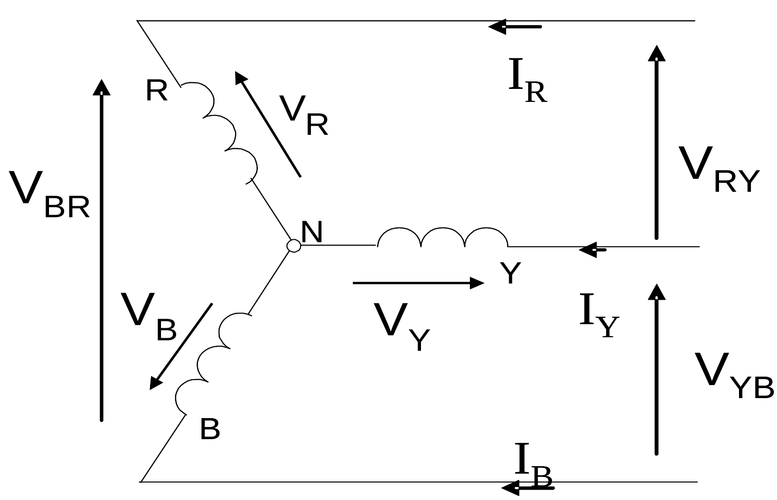
Current phase (I_{PH}) : I_r, I_y, I_b

Line voltage (V_L) : V_{RY}, V_{YB}, V_{BR}

Line current (I_L) : I_R, I_Y, I_B

$I_N = I_R+I_Y+I_B$

- V_{RY}, V_{YB} and V_{BR} are called line voltage
- V_R, V_Y and V_B are called phase voltage

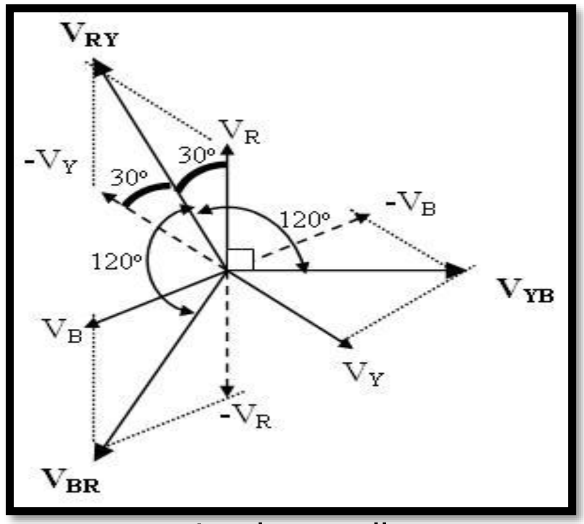


From Kirchoff voltage law we have

$$V_{RY} = V_R - V_Y = V_R + (-V_Y)$$

$$V_{YB} = V_Y - V_B = V_Y + (-V_B)$$

$$V_{BR} = V_B - V_R = V_B + (-V_R)$$



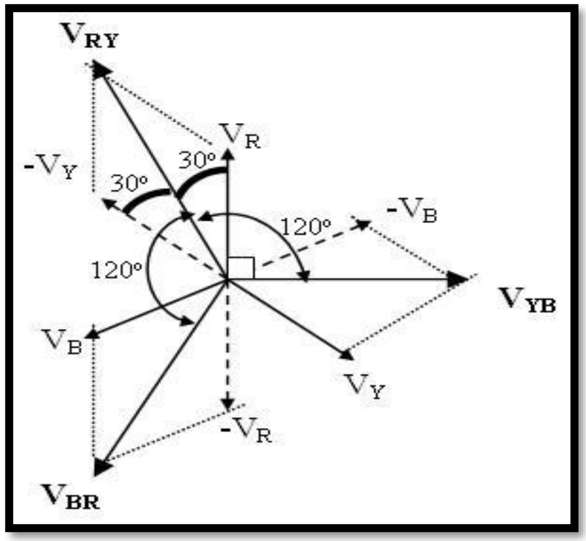
In phasor diagram

For balanced load V_R , V_Y and V_B are equaled but out of phase:

$V_{RY} = V_R\angle 30°$;

$V_{YB} = V_Y\angle -90°$;

$V_{BR} = V_B\angle 150°$;



therefore

$$V_{RY} = 2V_R \cos 30^o = \left(\sqrt{3}\right)V_P$$

$$V_{BR} = 2V_B \cos 30^o = \left(\sqrt{3}\right)V_P$$

$$V_{YB} = 2V_Y \cos 30^o = \left(\sqrt{3}\right)V_P$$

$$V_L = \left(\sqrt{3}\right)V_P$$

$$I_L = I_P$$

TEST-MIND!!!

Three similar resistors are connected in star across 400V, 3 phase lines. The line current is 5A. Calculate the value of each resistor. To what value should the line voltage be changed to obtain the same line current with the resistors are in delta connected?

Power in 3-Phase System

- DC power system : $W = IV$
- AC power system : $W = IV \cos\theta$ / phase

- Power for 3-phase system (refer to *phase* element)

$$P = 3V_P I_P \cos\varphi$$

- Power for 3-phase system (refer to *line* element)

$$P = \sqrt{3} V_L I_L \cos\varphi$$

Summary of 3-Phase System

Characteristic	Star Connection	Delta Connection
Symbol	⅄ or Y	△
Voltage	$V_L = \sqrt{3}\ V_{PH}$	$V_L = V_{PH}$
Current	$I_L = I_{PH}$	$I_L = \sqrt{3}\ I_{PH}$
Balance Condition	$I_N = I_R + I_Y + I_B = 0$	$V_{cs} = V_{RY} + V_{YB} + V_{BR} = 0$
Power in 1ϕ	$V_{PH} \cdot I_{PH} \cdot \text{kos}\ \varphi$	$V_{PH} \cdot I_{PH} \cdot \text{kos}\ \varphi$
Power in 3ϕ		
- Phase element	$3 \cdot V_{PH} \cdot I_{PH} \cdot \text{kos}\ \varphi$	
- Line element	$\sqrt{3} \cdot V_L \cdot I_L \cdot \text{kos}\ \varphi$	

Tutorial

CHAPTER 1: ALTERNATING VOLTAGE AND CURRENT

1. List TWO (2) laws related in generating of alternating current.

2. Write the equation for the sine wave in Figure 1.

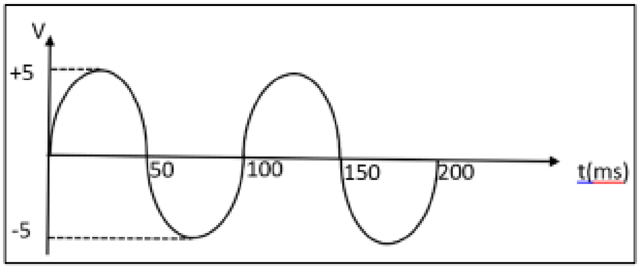


Figure 1

3. Calculate the rms voltage of an average voltage of 12V.

4. What is the difference between DC and AC electricity?

5. By referring to Figure 2 of an AC voltage measured over time, calculate:

i) Period
ii) Angular velocity
iii) Amplitude

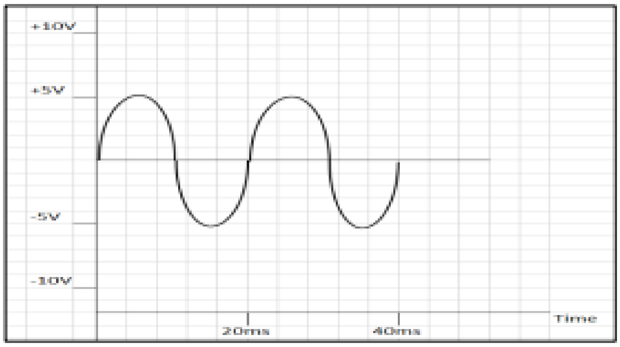


Figure 2

6. The current in an AC circuit at any time t seconds is given by i = 40 sin (60πt + 0.36) A. Calculate:

i) The period time and frequency
ii) The value of the current when t=0

7. Explain faraday's law involve in generating ac current.

8. List TWO (2) methods of generating alternating current.

9. The voltage in AC circuit is given by V = 10 sin 62.8t Volt. Calculate:

i) The frequency and period time
ii) The value of the voltage at t = 2ms

10. Calculate the rms voltage if peak to peak value voltage is 14V.

11. An alternating current is given i(t) = 100 sin (200πt + 0.45) A. Calculate the period, root mean square (RMS) value and the instantaneous value when t=0s.

12. Based on Figure 3 below:

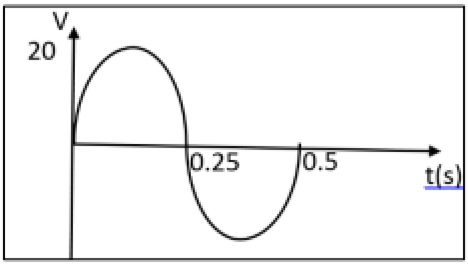


Figure 3

i) Define the time period, T of a sine wave.
ii) Find the value of time period, T
iii) State the peak voltage, Vp
iv) Write the sinusoidal waveform equation.

1. A coil has a resistance of 4 and an inductance of 9.55 mH. Calculate

i. the reactance **(XL=3Ω)**
ii. the impedance **(Z=5Ω)**
iii. the current taken from **(I=48A)**

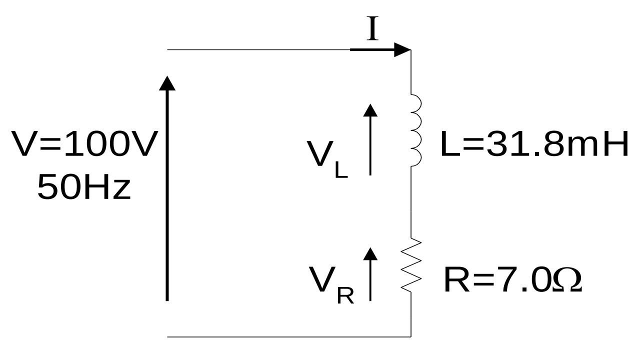
a 240V, 50 Hz supply. Determine also the phase angle between the supply voltage and current. **(36.87◦ lagging)**

2. A coil consists of a resistance of 100 and an inductance of 200 mH. If an alternating voltage, *v*, given by ***v*=200 sin 500*t*** volts is applied across the coil, calculate

i. The circuit impedance **(Z=141.4Ω)**
ii. The current flowing **(I=1A)**
iii. The p.d. across the resistance **(Vr=100V)**
iv. The p.d. across the inductance **(Vl=100V)**
v. The phase angle between voltage and current.**(φ=45◦ or π/4 rads)**
vi. Draw the phasor diagram for voltages.

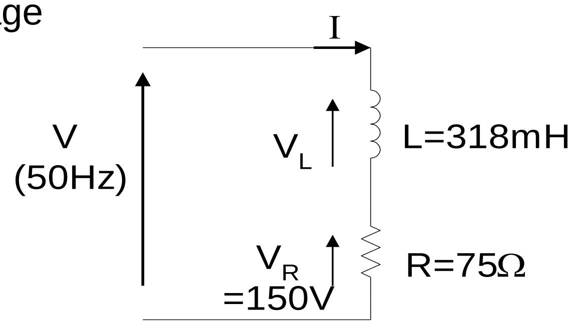
3. A resistance of 7.0Ω is connected in series with a pure inductance of 31.8mH. The circuit is connected to a 100V, 50Hz, sinusoidal supply. Calculate :

i. the circuit current
ii. the phase angle



4. A pure inductance of 318mH is connected in series with a pure resistance of 75Ω. The circuit is supplied from a 50Hz sinusoidal source and the voltage across the 75Ω .Resistor is found to be 150V. Calculate the supply voltage

.



5. A coil having a resistance of 12Ω and a inductance of 0.1H is connected across a 100V, 50Hz supply. Calculate:
   i. The reactance and the impedance of the coil;
   ii. The current
   iii. The phase difference between the current and the applied voltage

6. An coil hav a resistance 5Ω and a inductance of 0.5H. If it is connected to the AC power supply 240V, 50Hz, calculate:
   i. current
   i. power factor
   iii. draw the phase diagram

7. A capacitor *C* is connected in series with a 40 resistor across a supply of frequency 60 Hz. A current of 3A flows and the circuit impedance is 50 Ω. Calculate
   i. the value of capacitance, *C*, **(88.42 μF)**
   ii. the supply voltage, **(150V)**
   iii. the phase angle between the supply voltage and current, **(36.87◦ leading.)**
   iv. the p.d. across the resistor **(120V)**
   v. the p.d. across the capacitor. **(90V)**
   vi. Draw the phasor diagram.

8. A capacitor of 8.0mF takes a current of 1.0A when the alternating voltage applied across it is 230V. Calculate:
   i. The frequency of the applied voltage;
   ii. The resistance to be connected in series with the capacitor to reduce the current in the circuit to 0.5A at the same frequency;
   iii. The phase angle of the resultants circuit

9. A capacitor of 8.0mF takes a current of 1.0A when the alternating voltage applied across it is 230V. Calculate:
   i. The frequency of the applied voltage;
   ii. The resistance to be connected in series with the capacitor to reduce the current in the circuit to 0.5A at the same frequency;
   iii. The phase angle of the resultants circuit

10. A capacitor of 8.0mF takes a current of 1.0A when the alternating voltage applied across it is 230V. Calculate:
   i. The frequency of the applied voltage;
   ii. The resistance to be connected in series with the capacitor to reduce the current in the circuit to 0.5A at the same frequency;
   iii. The phase angle of the resultants circuit

11. A metal-filament lamp, rated at 750W, 100V, is to be connected in series with a capacitor across a 230V, 60Hz supply. Calculate:
   i. The capacitance required
   ii. The phase angle between the current and the supply voltage

12. Given L=120mH parallel with C=25μ, V=100V, 50 Hz supply.
   Calculate
   i. the branch currents, **(IL=2.65A, IC=0.755A)**
   ii. the supply current, **(I=1.864A)**
   iii. the circuit impedance, **(Z=53.64Ω)**
   iv. the power dissipated,**(P=0W)**

13. A 10Ω resistor connected in series with the capacitor 100μF. This circuit is connected to AC supply 100V, 50Hz. Calculate:-
   i. Current
   ii. Power factor
   iii. Draw the phase diagram

14. A coil of resistance 5Ω and inductance 120mH in series with a 100μF capacitor, is connected to a 300V, 50 Hz supply.
   Calculate
   (a) the current flowing, **(38.91A)**
   (b) the phase difference between the supply voltage and current, **(49.58◦)**
   (c) the voltage across the coil **(1467V)**
   (d) the voltage across the capacitor **(1239V)**

15. A circuit having a resistance of 12 W, an inductance of 0.15H and a capacitance of 100 mF in series, is connected across a 100V, 50Hz supply. Calculate:
   (a) The impedance;
   (b) The current;
   (c) The voltage across R, L and C;
   (d) The phase difference between the current and the supply voltage

CHAPTER 3: RESONANCE

1. A circuit with 0.2H inductor and internal resistor 10Ω connected series with capacitor 60µF. This circuit is connected to AC 200v source. Calculate:
   i. Resonance frequency, f_r
   ii. Current, I
   iii. Power in resonance, P_m

2. One choke with 0.5H inductor and internal resistor 10Ω connected series with capacitor 40µF. The voltage is 200v. Calculate,
   i. Maximum current
   ii. Resonance frequency
   iii. Q factor
   iv. Potential difference across inductor and capacitor

3. One circuit with internal resistor 20Ω dan inductor 0.55H connected parallel with capacitor 55µF. This circuit is connected to a supply of 100v with variable frequency. Calculate :
   i. resonance frequency
   ii. current circuit
   iii. Q factor

4. Calculate the quality factor (Q) of a series circuit that resonance at 6kHz, has equal reactance of 4kΩ each and a resistor value of 50Ω.

5. A coil of inductance 120mH are connected in series with a capacitance of 2µF and a resistance of 12Ω across 50V with variable frequency supply.
   i. Determine the bandwidth of the circuit during the resonance
   ii. Calculate voltage across each component at resonance
   iii. Frequency applied to the circuit.

.

1. A transformer has 800 turns on the primary and a turns ratio of 0.25. How many turns are on the secondary?

2. A doorbell requires 0.4 A at 6V. It is connected via a transformer whose primary coil contains 2000 turns to a 120V AC line. Calculate:-
   i. (a) N_S
   ii. (b) I_P

3. Illustrate the parts of an ideal transformer.(5m)

4. Identify the importance of the core material. (3m)

5. A 50 kVA, single-phase transformer has 500 turns on the primary and 100 turns on the secondary. The primary is connected to 2500V, 50Hz supply. Calculate the following :- (9m)
   i. The secondary voltage on open circuit
   ii. The current flowing through the windings on full load
   iii. The maximum value of flux

6. A single phase ideal transformer contains 3000 circumferences at primary coil and 800 circumferences at secondary coil. Primary coil is connected to 240VAC, 50Hz supply. Calculate:- (8m)
   i. Secondary voltage
   ii. Current on secondary coil if the current on primary coil is 5A.
   iii. Transformer power on primary and secondary coils

7. The transformer in Figure 1 has a turns ratio of 3. What is the voltage across the secondary winding? **(360v)**

Figure 1

8. The transformer in Figure 2 has a turns ratio of 0.2. What is the secondary voltage? **(24v)**

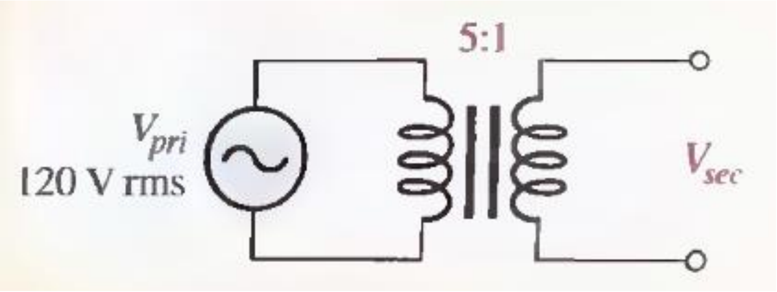


Figure 2

9. A primary voltage of 120v is reduced to 12v ac. What is the turn ratio? **(0.1)**

10. A transformer has 500 primary turns and 3000 secondary turns. If the primary voltage Is 240V, determine the secondary voltage, Assuming an ideal transformer. (1440v)

11. An ideal transformer has a turns ratio of 8:1 and the primary current is 3A when it is supplied at 240V. Calculate the secondary Voltage and current.**(30V, 24A)**

12. An ideal transformer, connected to a 240V mains, supplies a 12V, 150W lamp. Calculate the transformer turns ratio and the current taken from the supply. **(0.05, 0.625A)**

13. A 12Ω resistor is connected across the secondary winding of an ideal transformer whose secondary voltage is 120V. Determine the primary voltage if the supply current is 4A. (**300v)**

1. Three similar resistors are connected in star across 400V, 3 phase lines. The line current is 5A. Calculate the value of each resistor. To what value should the line voltage be changed to obtain the same line current with the resistors are in delta connected?

2. Three identical impedances are connected in delta to a three phase 400V supply. The line current is 34.65A and the total power taken from the supply is 14.4kW. Calculate the resistance and reactance values of each impedance.

3. Three similar coils are connected in star taken at a total power of 1.5kW at a p.f of 0.2 lagging from a 3-phase 400V 50Hz supply. Calculate the resistance and inductance of each phase.

4. Find :-
   i. Phase Impedance, ZPH
   ii. Phase Current, IPH
   iii. Line Current, IL
   iv. Phase Voltage, VPH
   v. Single phase power, P1ϕ
   vi. Three phase power (phase element), P3ϕ
   vii. Three phase power (line element), P3ϕ

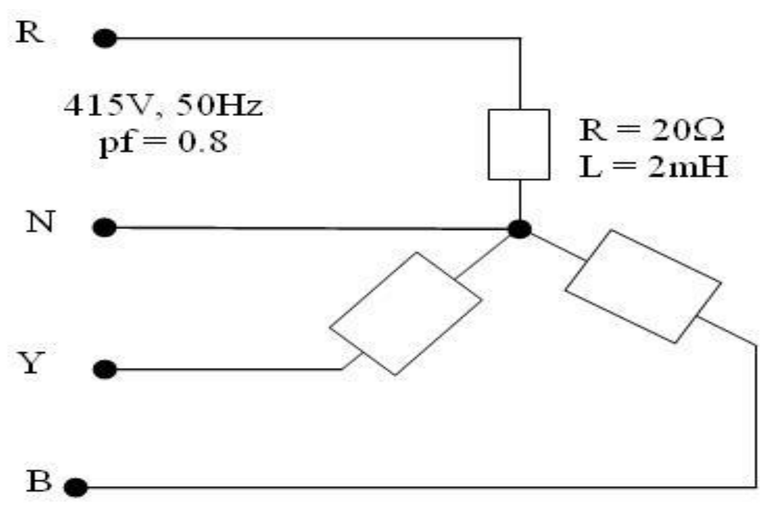


Figure 1

5. Refer to Figure 2, find :-

i. Phase Impedance, ZPH

ii. Phase Current, IPH

iii. Line Current, IL

iv. Three phase power (line element), P3ϕ

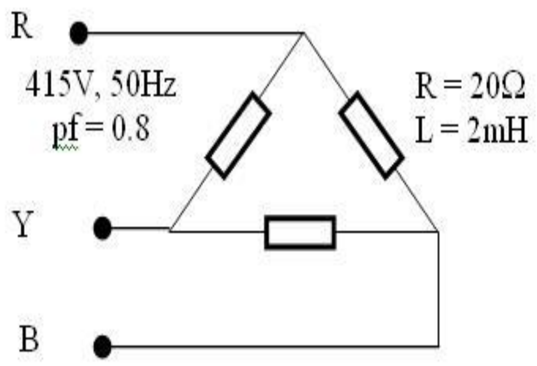


Figure 2

6. Three coil each having a resistance of 20Ω and inductive reactance of 15Ω are connected to a 400V, 3 phase 50Hz supply. Calculate:-

i. The line current

ii. Power factor

iii. Power drawn from the supply

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